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A LIMITED EVALUATION OF PREDICTING PILOT OPINION OF AIRCRAFT HANDLING QUALITIES IN THE LANDING PHASE OF FLIGHT USING THE CONTROL ANTICIPATION PARAMETER AND BANDWIDTH CRITERION (HAVE CAP)

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FINAL REPORT

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AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

This technical report (AFFTC-TR-95-78, *A Limited Evaluation of Predicting Pilot Opinion of Aircraft Handling Qualities in the Landing Phase of Flight Using the Control Anticipation Parameter and Bandwidth Criterion [HAVE CAP]*) was submitted under Job Order Number M94C1400 by the Commandant, USAF Test Pilot School, Edwards Air Force Base, California 93524-6485.

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This technical report presents the results of a limited evaluation of predicting pilot opinion of aircraft handling qualities in the landing phase of flight using the control anticipation parameter (CAP) and bandwidth criteria. The objective of this flight-test was to evaluate the validity of predicting pilot opinion using the CAP and bandwidth criteria. The CAP was defined as in MIL-STD-1797A, *Flying Qualities of Piloted Aircraft*. The bandwidth criterion used the current definition in MIL-STD-1797A along with a new dropback criterion. Actual pilot opinion was obtained by flying the Variable-Stability In-Flight Simulator Test Aircraft (VISTA) NF-16D in the approach and landing phase of flight.

Testing was requested by the Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, and was conducted under the authority of the Commandant, USAF Test Pilot School. The results of this test will be used to revise the short-term pitch response requirements in MIL-STD-1797B. This flight-test complemented research done by the Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio (WL/FIGC), in predicting pilot opinion during the landing phase of flight.

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PREFACE

This technical report presents the results of a limited evaluation of predicting pilot opinion of aircraft handling qualities in the landing phase of flight using the control anticipation parameter (CAP) and bandwidth criteria.

Testing was requested by the Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, and was conducted under the authority of the Commandant, USAF Test Pilot School. The results of this test will be used to revise the short-term pitch response requirements in MIL-STD-1797B. This flight test complimented research done by the Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio (WL/FIGC), in predicting pilot opinion during the landing phase of flight.

The HAVE CAP test team deeply appreciated the assistance and guidance of several very talented people. This flight test would not have been possible without the help of Dave Leggett from the Flight Dynamics Laboratory, Roger Hoh and David Mitchell from Hoh Aeronautics, Inc., Lou Knotts, Eric Ohmitt, Tim Bidlack, and Jeff Peer from CALSPAN, and numerous other support personnel from Edwards Air Force Base.

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EXECUTIVE SUMMARY

This technical report presents the results of a limited evaluation of predicting pilot opinion in the landing phase of flight using the control anticipation parameter (CAP) and bandwidth criteria. The overall test objective was to evaluate discrepancies between the CAP and bandwidth criteria, and to evaluate the advantage of including a dropback with the bandwidth criterion. The overall test objective was satisified but some specific test points were not accomplished.

Tests were conducted by members of the USAF Test Pilot School Class 95A from 15 to 22 September 1995 at Edwards AFB, California. Nine practice sorties and two test support practice sorties were flown in the F-15, F-16, C-18, and T-38 aircraft. The actual test required 8 sorties for 10.5 hours of flight time. Testing was requested by the Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio (WL/FIGC), and complemented their research in predicting pilot opinion. Testing was conducted under authority of the Commandant, USAF Test Pilot School, under AFFTC Job Order Number M94C1400.

The HAVE CAP test aircraft was the Variable-Stability In-Flight Simulator Test Aircraft (VISTA) NF-16D, owned by the Flight Dynamics Directorate of Wright Laboratory and operated by the Flight Research Department of CALSPAN Advanced Technology Center. This test used the VISTA variable stability system (VSS) to simulate aircraft predicted to have Level 1, 2, and 3 handling qualities.

Flight testing consisted of an offset landing task performed in the VISTA aircraft. Aircraft handling qualities were evaluated using 10 different VSS configurations. Cooper-Harper ratings were assigned by the project test pilots after each evaluation. Specialized runway markings and dedicated ground support were used to determine the level of pilot performance achieved during each rated landing event. Cooper-Harper pilot ratings were correlated and compared to each flight control configuration's CAP, bandwidth, and bandwidth with dropback criteria. The level of correlation for each handling qualities predictor was then analyzed with respect to the flight control configurations short period dynamic characteristics.

Overall, both the CAP and bandwidth criteria correlated with actual pilot opinion approximately 50 percent of the time. Incorporating the current definition of dropback to the bandwidth criterion decreased the correlation to approximately 30 percent. However, flight test results indicated excessive dropback and influenced pilot opinion only at relatively high values of CAP or short period natural frequencies. Applying the dropback definition to bandwidth in those regions where pilot opinion was influenced by excessive dropback increased the correlation to approximately 70 percent.

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INTRODUCTION

GENERAL

The MIL-STD-1797A, *Flying Qualities of Piloted Aircraft,* used the control anticipation parameter (CAP) and the bandwidth criterion to predict pilot opinion of aircraft handling qualities about the longitudinal axis. For the next revision of MIL-STD-1797, a new criterion called dropback was proposed for inclusion with the bandwidth criterion. Comparisons of current and proposed criteria by the Flight Dynamics Laboratory and the Air Force Institute of Technology, Wright-Patterson AFB, Ohio, showed the different criteria did not predict the same level of handling qualities in the landing phase of flight.

Project HAVE CAP's goal was to evaluate the discrepancies between CAP and the bandwidth criteria in the landing phase of flight as well as the advantage of including the dropback criterion with bandwidth. Flight tests using the Flight Dynamics Laboratory's Variable-Stability In-Flight Simulator Test Aircraft (VISTA) were conducted by members of USAF Test Pilot School Class 95A from 15 to 22 September 1995 at Edwards AFB. Eleven practice and test support sorties, requiring 12.0 flight hours, and eight test sorties, requiring 10.5 hours of flight time, were performed. Testing was requested by the Flight Dynamics Laboratory (WL/FIGC) and complemented their research in predicting pilot opinion. Testing was conducted under authority of the Commandant, USAF Test Pilot School, under Air Force Flight Test Center (AFFTC) Job Order Number (JON) M94C1400.

HISTORICAL BACKGROUND

New handling qualities criteria have been developed to predict pilot opinion of highly augmented aircraft. Many of the new handling qualities metrics are applicable to aircraft in the landing phase of flight (Bibliography 1 through 21). The handling qualities parameters compared in this flight test were the CAP and the bandwidth criteria, as defined in MIL-STD-1797A, and supplemented by the addition of a recommended dropback criterion (References 1 through 4). As applied in this flight test, these three handling qualities criteria predicted pilot opinion through the aircraft's short term pitch response. The MIL-STD-1797A states "the importance of the short-term pitch response reflects the high attention it has been given and the great need for further study to derive a clear-cut, generally applicable set of requirements" (Reference 5).

In many instances these criteria did not predict the same pilot opinion level. The MIL-STD-1797A defined each level as:

Level 1 Satisfactory: Flying qualities clearly adequate for the mission flight phase. Desired performance is achievable with no more than minimal pilot compensation.

Level 2 Acceptable: Flying qualities adequate to accomplish the mission flight phase, but some increase in pilot workload or degradation in mission effectiveness, or both, exists.

Level 3 Controllable: Flying qualities such that the aircraft can be controlled in the context of the mission flight phase, even though pilot workload is excessive or mission effectiveness is inadequate, or both (Reference 5).

The Air Force Institute of Technology in conjunction with the Flight Dynamics Laboratory, at Wright-Patterson Air Force Base, Ohio, has conducted research to evaluate differences among these handling qualities criteria outlined in MIL-STD-1797A. Results of this research will be used to derive a more clearcut, generally acceptable, comprehensive flying qualities criteria to predict pilot opinion in the next revision of MIL-STD-1797. Appendix D contains an indepth discussion of CAP, bandwidth, dropback and the mappings between the different domains.

TEST ITEM DESCRIPTION

General Aircraft Description:

The HAVE CAP testbed was the NF-16D VISTA, USAF S/N 86-0048. It was a USAF test aircraft owned by the Flight Dynamics Directorate of Wright Laboratory, Wright-Patterson AFB, Ohio and operated by the Flight Research Department of CALSPAN Advanced Technology Center. The aircraft was a highly modified Block 30 Peace Marble II variant of a two-seat F-16. Pilot in

command controls were moved from the front cockpit to the rear. The front cockpit had both a center and side stick with variable-feel. The front cockpit center control stick and rudder pedals were used by the evaluation pilot to provide inputs to a programmable flight control and variable stability system (VSS). The aircraft's basic empty weight (aircraft weight excluding usable fuel) was 21,750 pounds.

The aircraft had a dorsal fairing, heavyweight landing gear, an F110-GE-100 engine, and Block 40 avionics. Modifications to the aircraft included the additions of a production digital flight control system (DFLCS), instrumentation data acquisition system, and VSS interface. Items removed from the production aircraft included the 20 millimeter gun, ammunition drum, radar warning system, chaff flare dispenser, nuclear weapon capability, advanced medium-range air-to-air missile (AMRAAM) capability, and expanded envelope gun sight. The layout of major components added to the VISTA are shown in Figure H1.

<u>Test Item Instrumentation</u>:

The VISTA was equipped with an Ampex AR700 airborne digital data recorder. Two hundred channels of data were recorded at 100 samples per second with 12 bit resolution. An additional 60 analog VSS parameters were also recorded. The VISTA was equipped with two videocassette (VHS) video recorders, capable of recording the head-up display (HUD) and multifunction display (MFD).

<u>Variable Stability System</u>:

The VISTA's flight control system simulated a classical second order response for the different VSS configurations. To achieve the desired VSS configurations, VISTA used angle of attack (AOA), pitch angle, pitch rate, and velocity feedback loops. The angle of attack and pitch rate feedback loops were used to achieve the desired short period dynamic characteristics. The pitch angle and velocity feedback loops were used to decrease the influence of the phugoid mode. To simulate each configuration, the VSS provided computer-controlled commands to the horizontal tails, rudder, flaperons, and engine.

The aircraft's phugoid, lateral-directional and center control stick dynamics were held constant throughout flight testing. For a detailed description of the VISTAs aircraft, control stick and actuator dynamic models refer to Appendix H.

In the event of a problem with the VSS flight controls or its handling qualities, the rear seat safety pilot was able to disengage the front seat stick and throttle. In addition to manual disengages by either pilot, the VISTA control system contained over 100 automatic trips. These safety monitors protected the aircraft from excessive loads, sensor or computer failures, and structural excitation.

TEST OBJECTIVES

The overall test objective was to evaluate discrepancies between the CAP and bandwidth criteria, and to evaluate the advantage of including a dropback with the bandwidth criterion in predicting pilot opinion in the landing phase of flight for a generic Class IV aircraft, or one which was highly maneuverable. Actual pilot opinion was correlated to predicted pilot opinion in areas of agreement and disagreement between the various criteria. Refer to Appendix D for a detailed discussion of CAP, bandwidth, dropback, and the mappings between the different domains.

To obtain pilot opinion regarding the longitudinal handling qualities of aircraft throughout the CAP and bandwidth domains, VISTAs short period natural frequency and damping ratio were varied. Each specific short period natural frequency and damping ratio combination was referred to as a VSS configuration and are described in Appendix A. Each VSS configuration was evaluated using a high-gain lateral offset landing task as described in the Test Methods section of this report. Specific objectives of the flight test were:

1. Areas of Agreement and Disagreement: Obtain and evaluate qualitative and quantitative pilot opinion and Cooper-Harper pilot ratings in those areas where the criteria agreed and disagreed.

2. Dropback Line: Obtain and evaluate qualitative and quantitative pilot opinion and Cooper-Harper pilot ratings about the dropback line. The dropback line was that line where, if crossed going from acceptable dropback to excessive dropback, one level must be added to the bandwidth criterion while the CAP level remained the same. In other words, if an aircraft predicted to be Level 1 by

the bandwidth criterion exhibited excessive dropback, it would be predicted Level 2 by bandwidth using dropback. For a detailed description of the dropback criterion and the dropback line see Appendix D.

3. Minimum Short Period Natural Frequency (ω_{sp}) Region: Obtain and evaluate qualitative and quantitative pilot opinion and Cooper-Harper pilot ratings in the minimum ω_{sp} region. The minimum ω_{sp} region was the minimum ω_{sp} for the respective CAP Level 1 or 2 for Category C phases of flight as defined in MIL-STD-1797A.

4. Areas Across the Jump Line: Obtain and evaluate qualitative and quantitative pilot opinion and Cooper-Harper pilot ratings across the jump line. The jump line was a line in the CAP domain where, if ω_{sp} was increased or the short period damping ratio (ζ_{sp}) was decreased, the bandwidth would instantaneously go from a high frequency to a low frequency. Appendix D contains a description of the jump line.

5. Pilot Opinion Trends: Evaluate pilot opinion trends for those points that satisfy objectives 1 through 4.

6. Supporting Data: Collect and archive supporting data for future handling qualities analyses for the Flight Dynamics Laboratory and the Air Force Institute of Technology.

Evaluation Criteria: Pilot opinion was quantified using the Cooper-Harper and pilot induced oscillation (PIO) rating scales (Appendix C) based on the desired and adequate criteria set forth in the Test Methods section of this report. Qualitative pilot opinion was gathered after each lateral offset maneuver. Included in these comments were weather effects such as winds and turbulence, with turbulence rated using the standard light, moderate and severe descriptors. Comments also included firmness of touchdown using soft, medium, and firm descriptors. All of the specific objectives in this flight test used the same evaluation criteria. Table 1 summarizes the specific objectives that each test point satisfied.

LIMITATIONS

Development and flight test of the VISTA aircraft were completed in January 1995. HAVE CAP was the first flight test project to utilize VISTA. The nature of this project required CALSPAN to simulate specific short period dynamic responses using VISTA. While the VISTA aircraft was found to be an excellent evaluation tool for use in examining configuration characteristics, immaturity of the system was noted in its capability to precisely match a requested VSS configuration with regard to short period dynamics. As a result, test objectives 2 and 4 could only be partially addressed and test objective 3 could not be met.

Prior to flight testing, 18 points were submitted to CALSPAN to determine which configurations could be adequately simulated or landed. Figure 1 portrays the short period frequency and damping parameters of the 18 points initially submitted to CALSPAN for fulfillment of the test plan. Six of the original points (specifically points B, F, L, M, N, O) were removed from the list due to these configurations either tripping off in-flight or providing an inadequate match to the requested configuration based on a preliminary analysis. Two of the points (C1 and C3) were removed because

Table 1
REQUIREMENTS TRACEABILITY MATRIX

Objective	Test Point
1. Areas of Agreement and Disagreement	A, C2, D, E, G, H, I, J, K and P
2. Dropback Line	E, G, H, I, J, K and P
3. Minimum ω_{sp} Region	P
4. Areas Across the Jump Line	A and D
5. Pilot Opinion Trends	A, C2, D, E, G, H, I, J, K and P
6. Supporting Data	A, C2, D, E, G, H, I, J, K and P

Note: ω_{sp} - short period natural frequency

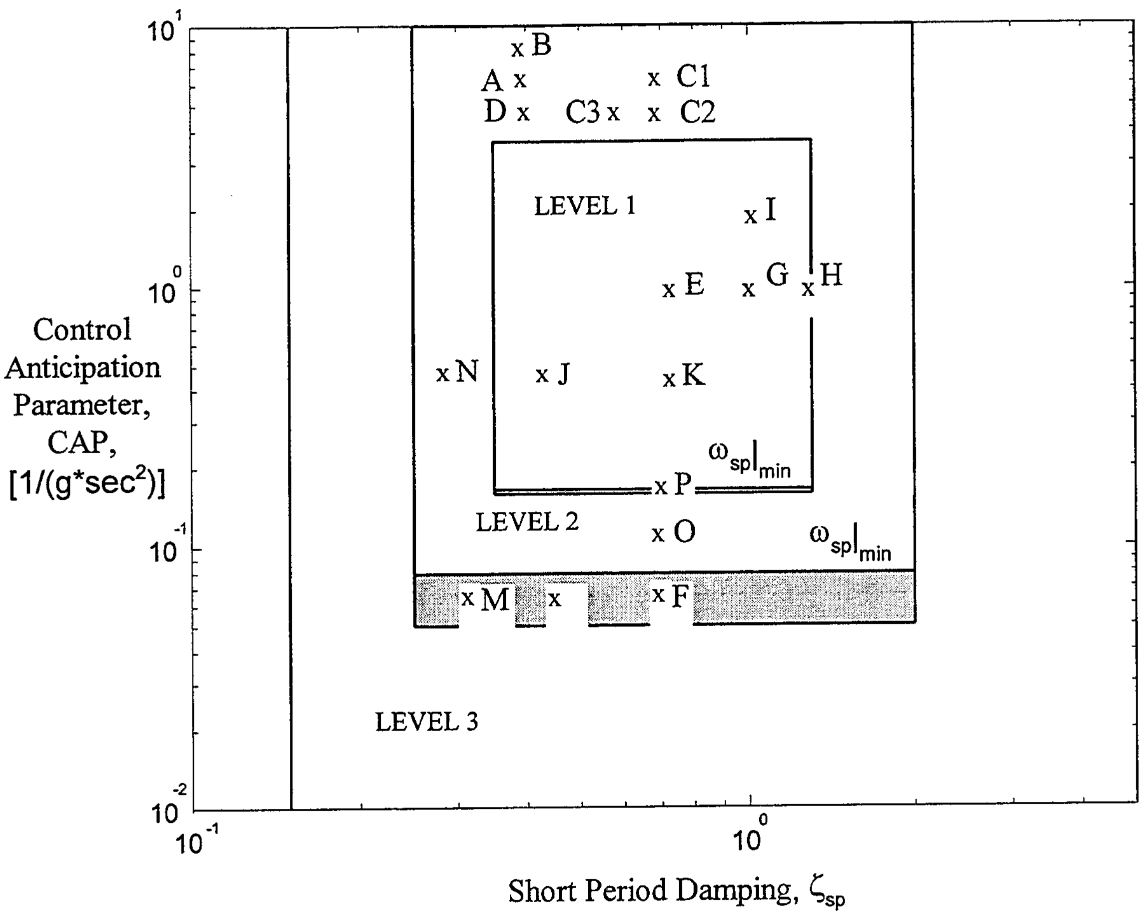

Figure 1 Test Points Initially Submitted to CALSPAN Prior to Flight Test ($1/T_{\Theta_2} = 0.45$, $n/\alpha = 4.01$)

their location was essentially encompassed by test point C2. Preliminary analysis of the remaining 10 points (A, C2, D, E, G, H, I, J, K, P) suggested they were within regions of interest for purposes of satisfying the objectives and were considered adequate. After the flight test, more extensive analysis was completed and showed these 10 points exhibited both a decrease in the damping ratio and an increase in CAP. In essence, when viewed in the CAP domain as shown in Figure 2, all of the test points actually flown during the landing task evaluation exhibited a shift in location upward and to the left. These parameters were obtained by ensemble averaging multiple frequency sweeps in order to enhance the squared coherence of each VSS configuration's respective bode diagrams (see Appendix J). A lower order equivalent systems (LOES) match was then generated by holding high frequency zero ($1/T_{\Theta_2}$) constant.

With regard to the dropback line referenced in test objective 2, all VSS configurations exhibited excessive dropback, thus trends on either side of the line could not be determined. However, an evaluation of pilot opinion trends could be made with regard to VSS configurations which progressively approached the dropback line from the excessive side. Because an evaluation of pilot opinion trends could not be made for acceptable dropback points, the test objective was only partially fulfilled. Regarding the jump line of test objective 4, collected data resulted in the development of trend information with regard to pilot ratings as the jump line was approached from increasing values of CAP. However, with no test

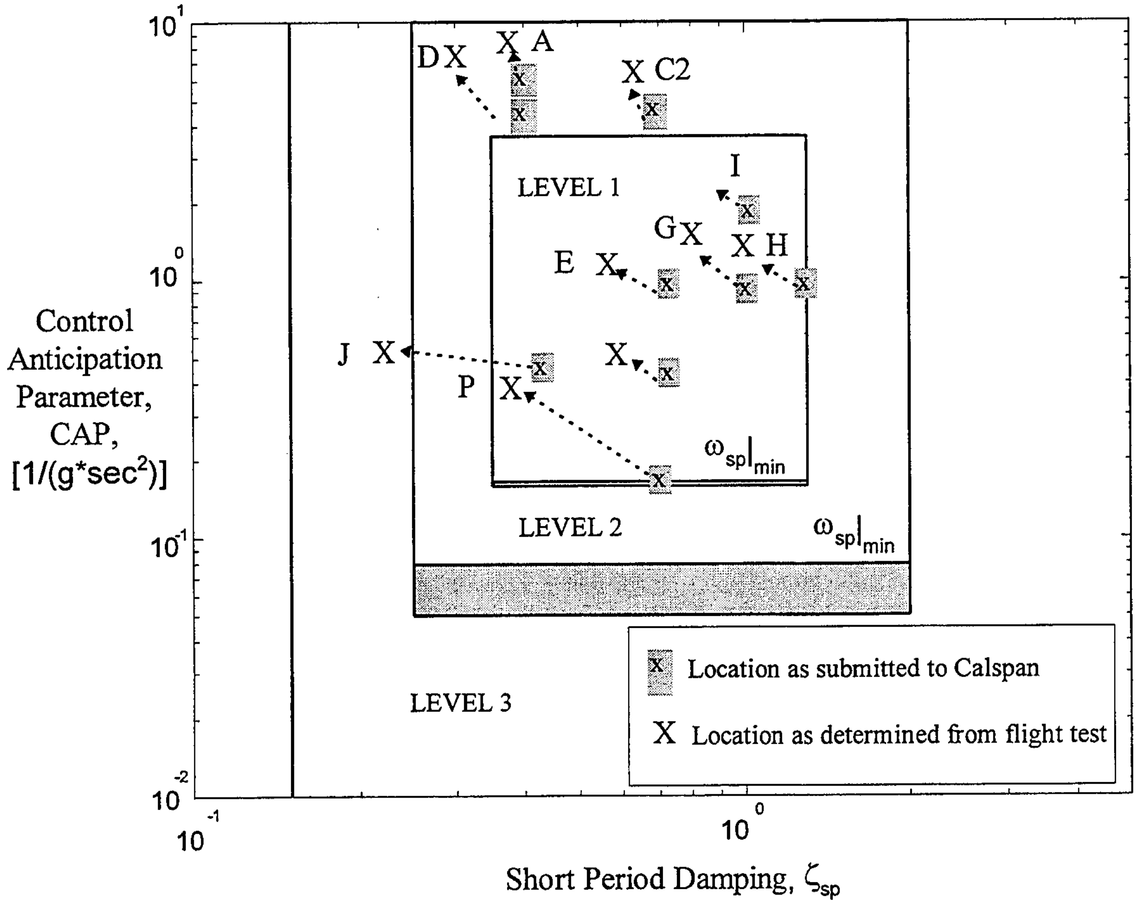

Figure 2 Actual CAP Parameters After Flight Test ($1/T_{\Theta_2} = 0.45$, $n/\alpha = 4.01$)

points above the jump line, the test objective was once again only partially fulfilled.

Lastly, objective 3 was not met. Preflight simulation on the VISTA suggested at least one of the test points would lie within the minimum short period natural frequency region in the CAP domain, which would satisfy this objective. However, postflight analysis revealed that the requested test points could not be accurately simulated by VISTA throughout the landing phase of flight, or were actually outside the desired region. Data were obtained in the areas of agreement and disagreement (objective 1) and the collection of supporting information (objective 6). Overall, the collected data provided substantial information regarding pilot opinion trends (objective 5) in a general sense and insight into the test objectives which were either partially fulfilled or not met as described above.

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TEST AND EVALUATION

GENERAL

The VISTA was used in this test because of the range of dynamic parameters it was capable of simulating. Ten different VSS configurations with a broad range of short period dynamics were evaluated during an offset landing task. Four test pilots of varying backgrounds were used for a broad range of pilot experience. Table 2 below details the evaluation of the pilots' weapon system experience.

Table 2
EVALUATION OF PILOTS'
FLYING EXPERIENCE

Evaluation Pilot	Weapon System Experience
1	C-141B
2	GR-7 (Royal Air Force Harrier)
3	B-1B, B-52G/H, T-38A
4	U-2R, T-38A, T-37

Each of the four evaluation pilots rated the VSS configurations using the Cooper-Harper and pilot induced oscillation (PIO) rating scales during high gain lateral offset landing tasks. Frequency sweeps and pitch step responses were also flown to define and validate the VSS configurations' short period dynamics.

For some VSS configurations, handling qualities during tracking (HQDT) and pitch-capture tasks were flown before attempting to land those configurations. In this buildup approach, all VSS configurations with predicted Level 3 handling qualities underwent an initial evaluation composed of HQDT and pitch-capture tasks at approximately 10,000 feet pressure altitude. Additional VSS configurations with predicted Level 1 and 2 handling qualities were included in these buildups to maintain the aspect of blind testing by the evaluation pilots. Once the initial evaluation was accomplished for a particular VSS configuration, the determination as to whether a landing should be attempted was made using the HAVE CAP Flight Test Decision Tree presented in Figure F1.

During all of the flight tests, VISTA was configured with landing gear down and speedbrakes extended, at an onspeed angle of attack (AOA) of 11 degrees. This setup was required to set the initial conditions in the variable stability system at the proper load factor per angle of attack (n/α).

Prior to the actual evaluations, the evaluation pilots flew the landing task in a variety of different aircraft to familiarize them with the task over a broad range of aircraft handling qualities. The practice aircraft included the F-15, F-16, C-18, and T-38.

METHODS AND CONDITIONS

For this flight test, a VSS configuration was defined as a unique combination of VISTAs short period damping ratio and frequency. Appendix A, Tables A1 through A3 and Figures A1 through A3 present the 10 VSS configurations evaluated during the flight test along with their defining short period LOES characteristics and predicted handling qualities.

All VSS configurations were evaluated by CALSPAN in the ground simulation mode of VISTA prior to flight. Each VSS configuration was cleared by CALSPANs safety pilots or USAF Test Pilot School staff pilots prior to being flown by the evaluation pilots. Clearing flights started with normal straight-in approaches and progressed to the lateral offset. Those points which were predicted to have Level 3 handling qualities by at least one of the prediction methods were evaluated during an HQDT task and a pitch-capture task. For detailed descriptions of the test procedures used for these buildup tasks see Appendix E. Flight tests were limited to a maximum steady-state crosswind of 15 knots and a tailwind of 10 knots for safety and data quality considerations.

Each VSS configuration was flown at least three times by two different evaluation pilots. For each VSS configuration evaluated, the pilot performed at least three landings to quantitatively and qualitatively evaluate the handling qualities of that particular configuration. Offset landings were accomplished as described in the Test Procedures section. Pilot comments were recorded during every evaluation and culminated in a single Cooper-Harper and PIO rating for each configuration. Ratings were assigned after the final landing attempt of that

particular VSS configuration. These ratings were the pilots' overall evaluation taking into account the VSS configuration's performance and workload during the landing attempts.

The sorties were broken down with the intent of evenly distributing VSS configurations among the different pilots. No single pilot ended up with all predicted handling quality Level 3 VSS configurations, or conversely, all Level 1 VSS configurations. Rather, the attempt was made to evenly distribute VSS configurations among the pilots based principally on the predicted handling qualities of the various configurations. Further, during any particular sortie, only CALSPAN personnel, including the safety pilot, and the two project flight test engineers knew exactly which VSS configurations were being tested. Pilots were occasionally given the same test point without their knowledge to document their consistency.

TEST PROCEDURES

To ensure the VSS configurations flown had the proper dynamic characteristics, manual and programmed frequency sweeps and programmed pitch-step inputs were flown. Frequency sweeps were used to obtain data for frequency response analysis (FRA) while time responses from the step inputs were used to determine the dropback criterion.

Frequency Sweeps:

Frequency sweeps were flown between 10,000 and 12,000 feet pressure altitude. They were flown both manually and using the VISTAs programmed test input. The frequency range of the sweeps was from approximately 1 to 10 radians per second. Data were recorded by the onboard data acquisition system (DAS) at a rate of 100 Hz. The data were then reduced at a rate of 20 Hz. CALSPAN provided the data from the DAS. A minimum of 1,024 data points were required for the frequency response analysis. Recorded data parameters are listed in Table G1.

The FRA was performed through ensemble averaging with a program developed at the USAF Test Pilot School using MATLAB™. The CALSPAN took the resulting pitch rate to stick deflection Bode plots and performed a LOES match holding $1/T_{\Theta_2}$ fixed to identify the dynamic characteristics of each VSS configuration. The matches were assumed valid if they fell within the bounds specified by MIL-STD-1797A (Reference 5) and were used to obtain the short period natural frequencies and damping ratios defining the CAP and equivalent time delay. The Bode plots were also used for the bandwidth analysis.

Pitch-Step Inputs:

The time responses from the pitch-step inputs were used to measure dropback. These step inputs were generated using VISTAs programmed test input and were flown between 10,000 and 12,000 feet pressure altitude. The step input was applied until a steady-state pitch rate was obtained; the step input was then taken out. The data were collected with the onboard DAS at a sample rate of 100 Hz and then downloaded to a personal computer at a rate of 20 Hz. Recorded data parameters are detailed in Table G1.

Offset Landing Task:

The offset landing task began at a 300-foot lateral offset at 300 feet above ground level (AGL). The task was to maneuver the aircraft to land softly in a predetermined landing zone. Pilots assigned one Cooper-Harper rating and one PIO rating to the task landing for each VSS configuration tested and made qualitative comments on the configurations handling qualities. The comment card used is shown in Appendix C. Each pilot performed the task at least three times for each assigned VSS configuration prior to assigning a single Cooper-Harper and PIO rating for that configuration, while comments were gathered after each landing attempt. More than three landing attempts were flown per VSS configuration if the evaluation pilot required more landings to accurately assign the pilot ratings.

The VISTA was configured for the specific VSS configuration by the safety pilot on downwind. The test aircraft was established on final, approximately 5 miles from the threshold, offset 300 feet to the left of the runway centerline and configured for landing with gear down and speedbrakes extended. When onspeed for an 11-degree AOA approach, the VSS was engaged and the safety pilot transferred aircraft control to the evaluation pilot.

The evaluation pilot flew the instrument landing system (ILS) glideslope down final, on speed while maintaining the 300 feet left offset. At 500 feet

AGL, the front cockpit head-up display (HUD) was dimmed so it was not visible to the evaluation pilot, preventing flightpath marker (FPM) dynamics from influencing the task. The rear cockpit HUD was still visible to the safety pilot. At 300 feet AGL, referenced by the radar altimeter, the safety pilot called "Maneuver." The offset task setup is shown below in Figure 3.

At the safety pilot's "maneuver" call, the evaluation pilot maneuvered to lineup on the runway centerline and land in the touchdown zone box painted on the runway. The pilot attempted to land in the center of the desired box, on speed and on AOA, with a minimal sink rate. If the maneuver appeared unsafe, either pilot could initiate a go-around. If the VSS tripped off, the safety pilot immediately took control of the aircraft.

Landing Zone:

Specialized runway markings were painted on Runway 22 at Edwards AFB to delineate the desired and adequate touchdown zones. Standard 18-inch wide white paint lines were used for all markings. The desired landing zone was a 400 feet long by 25 feet wide box. The front of the desired zone was 800 feet down the runway. This placed the center of the desired zone 1,000 feet down the runway. The adequate landing zone was 1,000 feet long by 50 feet wide. The adequate zone was placed 600 feet down the runway. These distances also corresponded with the placement of the runway lights providing a backup in case the lines on the runway became obscured or otherwise unusable. The landing zone is shown in Figure 4.

Landing Task Evaluation:

The evaluation pilot used touchdown point information, firmness of touchdown and workload to assign a Cooper-Harper and PIO rating. The evaluation pilot received feedback on longitudinal touchdown position from the ground observers over the very high frequency (VHF) radio. The evaluation pilot and safety pilot assessed the lateral touchdown position. For the landing to be considered in a zone, both main gear were required to be on or inside the respective line.

Both the safety and evaluation pilot qualitatively assessed the landing as either soft, medium, or firm. Touchdown firmness was evaluated qualitatively and used in the Cooper-Harper rating. A soft landing was desired, medium was adequate, and firm was not adequate. A qualitative evaluation was used as no quantitative feedback was accurate or timely enough. Vertical velocity from the aircraft instruments was considered, but determined to be inaccurate due to the lag in the system while the vertical acceleration or velocity from the data acquisition system were not immediately available to the pilot. The same safety pilot flew on all test flights, providing consistency in landing firmness assessments between evaluation pilots. The evaluation pilot's touchdown firmness ratings were used when assigning the Cooper-Harper rating.

Immediately after flying a VSS configuration, the evaluation pilot combined the landing zone feedback, firmness of touchdown, and workload required to assign a Cooper-Harper and PIO rating. On downwind, the safety pilot flew the aircraft while the evaluation pilot answered questions on the comment card (Figure C1) to help evaluate the aircraft's handling qualities. The landing and pilot comments were recorded on the HUD videotape for postflight analysis and data transcription. A camera on the ground near the approach end of the runway also recorded the aircraft from final through touchdown for post flight analysis. The onboard DAS recorded the time response data for each landing.

In addition, the evaluation pilot assigned a workload rating for the configuration, to reflect the degree of compensation and associated workload required in the offset landing task. Workload was assessed on a scale from 1 to 10, where 1 indicated negligible workload (compensation not a factor in the landing task) and 10 indicated intense and extreme compensation and workload. Workload ratings are not reliable indicators for comparison between different pilots. However, workload ratings given by the same pilot for different configurations have some value as a qualitative indicator. Nevertheless, the workload rating was secondary and did not provide a primary source of

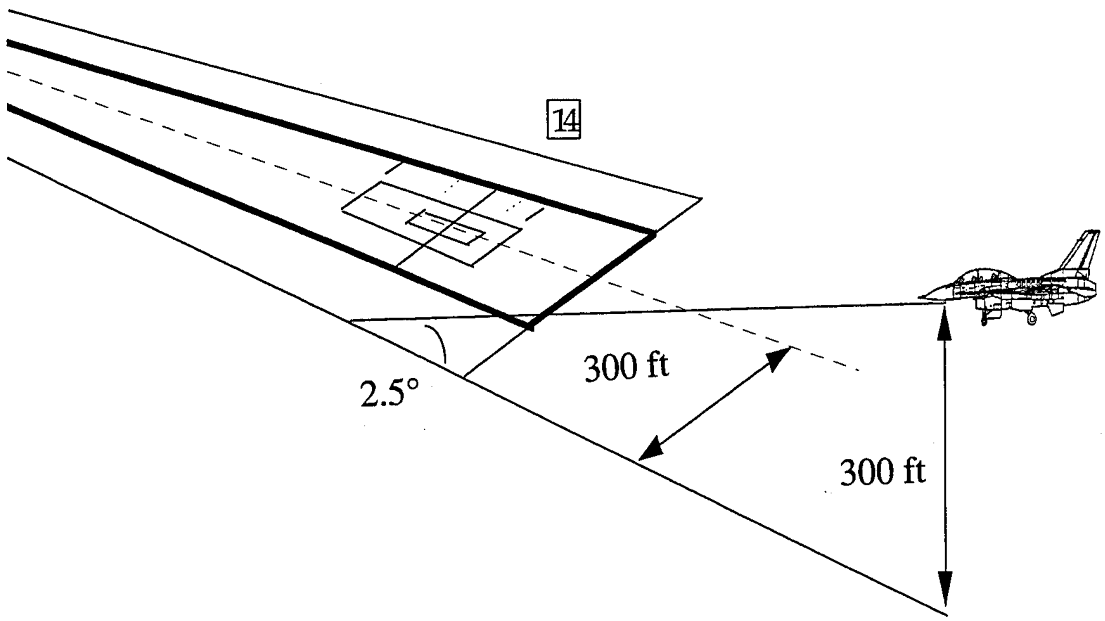

Figure 3 Lateral Offset Task Setup

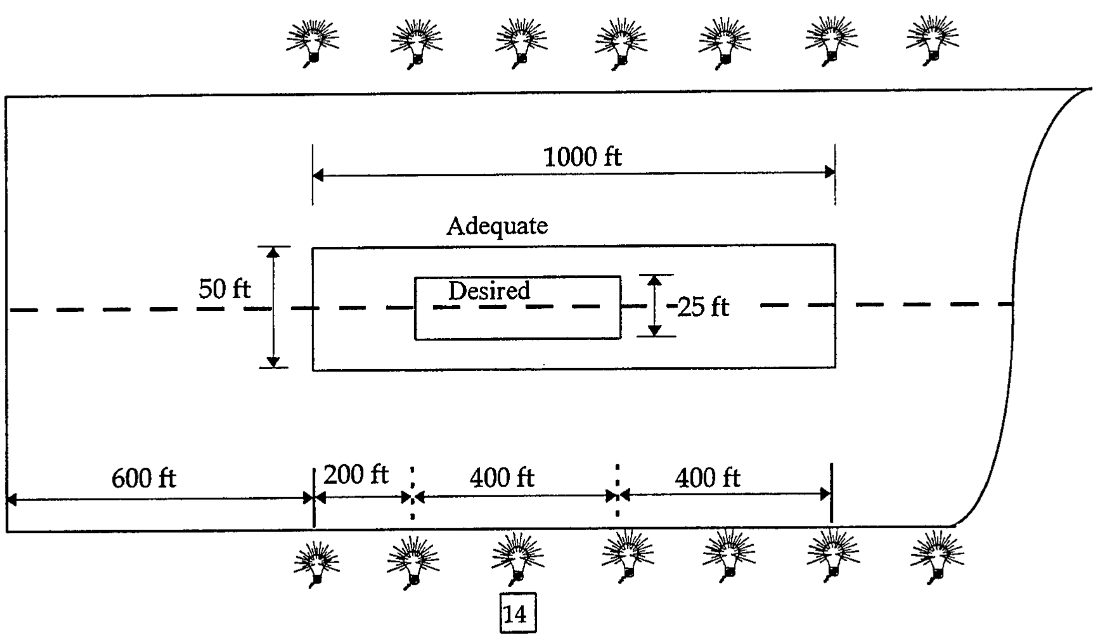

Figure 4 Landing Zone Markings and Dimensions

pilot opinion information. It was used only when necessary to reflect on the more formal Cooper-Harper and PIO rating scales.

After each flight test mission, the evaluation pilot reviewed the HUD videotape and test card comments. All appropriate mission data were entered into the pilot comment computer database. The database contained pilot remarks for each VSS configuration flown, Cooper-Harper, PIO and workload ratings, data parameters for each individual offset approach, and many other pertinent pieces of information. A complete summary of data recorded in the pilot comment database is contained in Appendix B.

RESULTS AND ANALYSIS

VSS Configurations:

The dynamic characteristics of the VSS configurations evaluated are presented in, Table A1. The locations on the CAP, bandwidth, and dropback domains are graphically depicted in Appendix A, Figures A1 to A3 and Tables A2 and A3.

Preflight analysis showed that all points except VSS configuration H were predicted to have excessive dropback using the short period approximation. However, during the LOES match identifying the configurations' dynamic characteristics, all VSS configurations generally migrated up and to the left in the CAP domain. Flight test results indicate that all VSS configurations had excessive dropback as shown in Figure A3 and for this reason objective 2, "Obtain and evaluate qualitative and quantitative pilot opinion and Cooper-Harper pilot ratings about the dropback line" could not fully be satisfied. Despite this, some very useful trends were seen as the points approached the dropback line. These trends are explained in further detail below.

Objective 4, "Obtain and evaluate qualitative and quantitative pilot opinion and Cooper-Harper pilot ratings across the jump line" could not be fully satisfied since VSS configurations A and D did not have low bandwidths due to a shelf type Bode plot as predicted by the short period approximation. The discrepancy between theory and flight test results may have been due to VISTA's flight control actuators. The actuators added phase into the system above the short period natural frequency which delayed the configurations' bandwidth jumping from a high to a low frequency. Despite this, valuable trends were seen as the VSS configurations approached the theoretical jump line shown in Figure D6.

Aircraft Evaluations:

Cooper-Harper and PIO ratings are presented for all configurations in Figures 5 and 6. Appendix B contains a database of all pilot comments and details of each landing evaluation flown.

The following text presents a synopsis of pilot comments by aircraft configuration. For each configuration, Tables 4 through 12 show a summary of pilot ratings, as well as the predicted handling qualities Level (1, 2 or 3) according to each of the CAP, bandwidth and bandwidth with dropback criteria. In addition, the tables list the short period natural frequency (ω_{sp}), short period damping ratio (ζ_{sp}), bandwidth frequency (ω_{BW}) and an estimated phase delay (τ_p) for each VSS configuration. Where a single pilot evaluated a given configuration on more than one occasion, pilot ratings given on each evaluation are listed in order separated by commas.

Pilot comments are summarized for each configuration in the first three paragraphs. The first paragraph describes the dominant comments common to all or most of the pilots for that VSS configuration, followed by the effect on pilot technique and task performance. Subsidiary pilot comments, such as those noted by only one or two pilots for that configuration are then discussed. Where warranted, further engineering analysis is given in a fourth paragraph.

Configuration A.

A synopsis of pilot comments for aircraft configuration A is presented in the following paragraphs and Table 3.

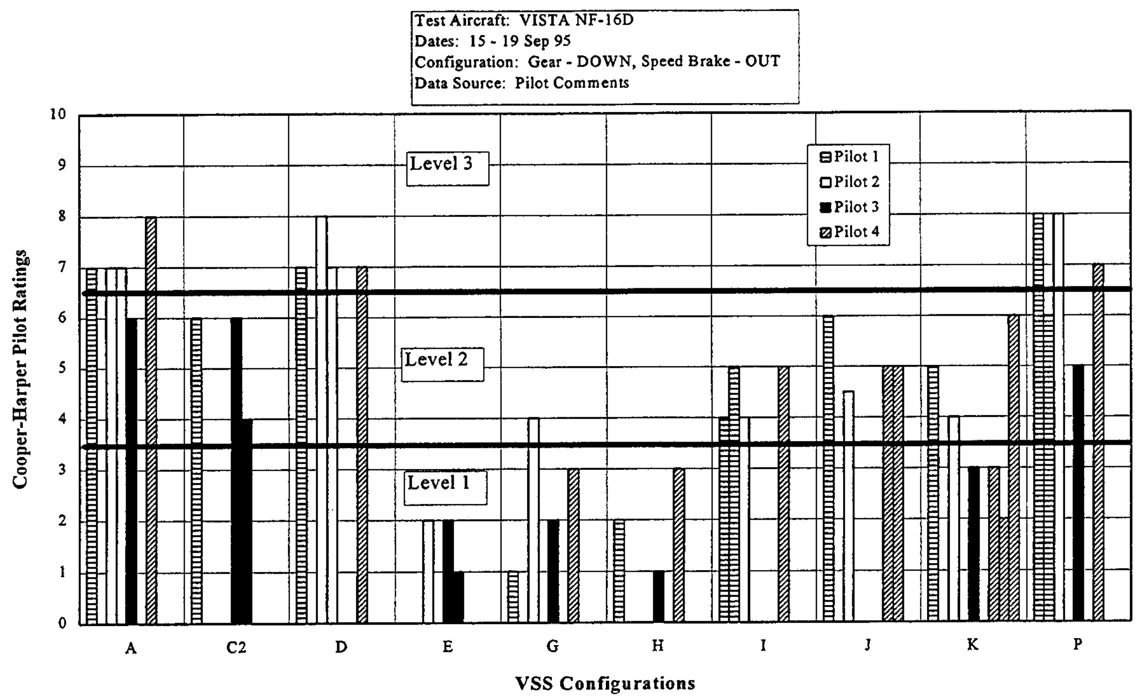

Figure 5 Cooper-Harper Ratings

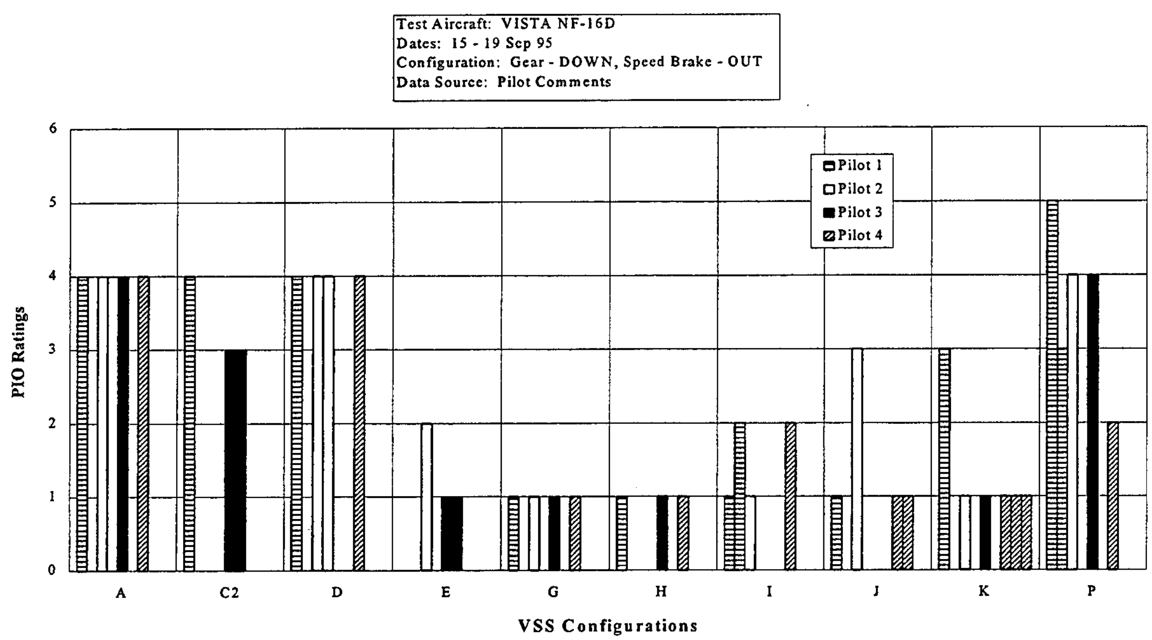

Figure 6 Pilot-Induced Oscillations Ratings

Table 3
VARIABLE STABILITY SYSTEM CONFIGURATION A - SUMMARY OF RESULTS

Predicted Level:	CAP: 2	Bandwidth: 2	Bandwidth w/ Drb: 2
Dynamics:	ω_{sp}: 5.68 ζ_{sp}: 0.384	ω_{BW}: 7.8	τ_p: 0.079 τ_θ: 0.040
Pilot	Cooper-Harper Rating	PIO Rating	Workload Rating
1	7	4	7
2	7, 7	4, 4	8, 8
3	6	4	8
4	8	4	8

Notes:
1. CAP - control anticipation parameter
2. Drb - dropback
3. ω_{sp} - short period natural frequency
4. ζ_{sp} - short period damping ratio
5. ω_{BW} - bandwidth
6. τ_p - estimated phase delay
7. τ_θ - lower order equivalent system time delay
8. PIO - pilot-induced oscillation

The main comments of all pilots found this configuration sensitive or touchy, with a small amplitude, quick pitch bobble or PIO being generated as soon as they entered the loop, even with small inputs. This pitch bobble could not be avoided in closed loop flight. Pilot 1 noted that even trim actuation excited the pitch bobble. Most pilots reported that aggressiveness aggravated the bobble. On two separate evaluations, Pilot 2 reported that aggressiveness only slightly worsened the problem or did not effect it beyond a certain limiting amplitude. Pilot 4 reported a PIO on one evaluation.

The net result of pilot performance characteristic was that pilot workload was intolerably high, with considerable compensation variously reported as "lag" or "lag-lead compensation," "tight in the loop control with small inputs," and "smoothing and lowering" of pilot gains. Pilot 2 reported a strong tendency to back out of the loop to avoid aggravating the bobble, resulting in less precise aircraft control and degraded task performance. Desired criteria were met on only 6 out of 14 landings.

Subsidiary pilot comments by Pilot 2 (on two evaluations of this configuration) and Pilot 3 reported that despite the pitch sensitivity the flightpath did not respond rapidly enough. This was an indication of excessive dropback. See Appendix D for a physical description and definition of the dropback criterion. Predictability was reported as poor by these two pilots. Due to encountering a divergent PIO, Pilot 4 considered control was in question and assigned the Cooper-Harper rating of 8.

The time histories of Pilot 4's PIO are presented in Appendix I. As seen, the pilot entered the PIO during the offset maneuver. However, there was sufficient altitude for the pilot to back out of the loop and recover from the PIO. A PIO was encountered a second time in the flare. This time the pilot did not back out of the loop due to the proximity of the ground.

Configuration C2.

A synopsis of pilot comments for aircraft configuration C2 is presented in the following paragraphs and Table 4.

Both evaluation pilots' main comments found this configuration sensitive, and reported a pitch bobble that was not divergent. Pertinent comments were "jittery and bouncy" (Pilot 1), and "nervous—darting up and down—extremely sensitive" (Pilot 3). In addition, both reported a tendency to overshoot and an inability to place the nose where required as the aircraft "gives you more than you wanted" in pitch (Pilot 3). These comments are again indicative of excessive dropback. The pitch bobble was nondivergent and could be damped with the pilot in the loop. Aggressiveness excited the motion.

Table 4
VARIABLE STABILITY SYSTEM CONFIGURATION C2 - SUMMARY OF RESULTS

Predicted Level:	CAP: 2	Bandwidth: 2	Bandwidth w/ Drb: 2
Dynamics:	ω_{sp}: 4.97 ζ_{sp}: 0.632	ω_{BW}: 6.7	τ_p: 0.084 τ_θ: 0.075
Pilot	Cooper-Harper Rating	PIO Rating	Workload Rating
1	6	4	5
2	---	---	---
3	6, 4	3, 3	8, 4
4	---	---	---

Notes:
1. CAP - control anticipation parameter
2. Drb - dropback
3. ω_{sp} - short period natural frequency
4. ζ_{sp} - short period damping ratio
5. ω_{BW} - bandwidth
6. τ_p - estimated phase delay
7. τ_θ - lower order equivalent system time delay
8. PIO - pilot-induced oscillation
9. --- not applicable

The result of pilot performance was a requirement for small inputs or backing out of the loop combined with anticipation. However, task performance did not appear to be greatly impacted; seven desired criteria touchdowns were achieved in nine landings. Nevertheless, at least one landing which did not meet either desired or adequate criteria was directly attributed by Pilot 3 to being forced the loop by the "squirrely" aircraft each time he tried to "get in the loop."

Subsidiary pilot comments, including categories such as control harmony, were also reported as poor by both pilots, indicating a discrepancy between control forces and handling qualities in the lateral and longitudinal axes. Though the lateral axis of the VISTA was not under study, poor control harmony may have adversely effected pilot opinion of the configuration overall.

Configuration D.

A synopsis of pilot comments for aircraft configuration D is presented in the following paragraphs and Table 5.

The main comment regarding VSS configuration was that it was sensitive in the pitch axis with a high frequency pitch oscillation or bobble noted by all pilots and described as small or low amplitude. It was excited "with every little input—actuating the trim button causes undesirable motions" (Pilot 1) and was "very difficult to prevent" (Pilot 2). All pilots reported that aggressiveness or tighter control worsened the bobble. Pilot 2 on his second evaluation reported that once excited to a given amplitude, further aggressiveness did not exacerbate the bobble.

Pilot performance resulted in smoothing of inputs or a more open loop control. Pilot 1 reported devoting much attention to control of the pitch axis. All pilots reported backing out of the loop in the flare to avoid these unpleasant motions. Seven out of 12 approaches met desired criteria, but workload was considered intolerably high by all pilots.

Subsidiary pilot comments consisted of Pilots 1 and 2 reporting problems with sustained maneuvering ability despite the initial pitch sensitivity indicating excessive dropback. Pilot 1 noted the stick forces were high despite the sensitivity, particularly in the offset maneuver and flare. Pilot 2 noted a sluggishness in sustained maneuver during both of his evaluations of this configuration, and also attributed some deterioration in task performance to this feature. Pilot 1 considered the motions controllable and predictable, while Pilot 2 considered the aircraft response overall unpredictable because of the difference between initial sensitivity and sluggish sustained maneuver. Pilot 2 also reported increasing the size of pitch inputs to compensate for the sluggishness after initial smoothing to avoid exciting the bobble.

Table 5
VARIABLE STABILITY SYSTEM CONFIGURATION D - SUMMARY OF RESULTS

Predicted Level:	CAP: 2	Bandwidth: 2	Bandwidth w/ Drb: 2
Dynamics:	ω_{sp}: 5.40 ζ_{sp}: 0.290	ω_{BW}: 6.1	τ_p: 0.077 τ_θ: 0.080
Pilot	Cooper-Harper Rating	PIO Rating	Workload Rating
1	7	4	7
2	8, 7	4, 4	7, 7
3	---	---	---
4	7	4	7

Notes:
1. CAP - control anticipation parameter
2. Drb - dropback
3. ω_{sp} - short period natural frequency
4. ζ_{sp} - short period damping ratio
6. τ_p - estimated phase delay
7. τ_θ - lower order equivalent system time delay
8. PIO - pilot-induced oscillation
9. --- not applicable

Configuration E.

A synopsis of pilot comments for aircraft configuration E is presented in the following paragraphs and Table 6.

The main comments of both pilots reported good handling qualities with negligible deficiencies or better.

In regards to pilot performance, Pilot 3 even adjusted the task to attempt to increase pilot gains, but still effectively met desired criteria on all six approaches. Pilot 2 met adequate criteria on two of three approaches without reporting a reason; however, this was his first evaluation of the program and he was consequently less familiar with the task.

Subsidiary comments consisted of remarks such as the only deficiencies noted were a very slight pitch bobble on two of the three approaches flown by Pilot 2, and not as crisp as ideal pitch control noted by Pilot 3 on his first evaluation. While this may be an indication of excessive dropback, it did not significantly degrade either pilots' rating since each pilot rated the VSS configuration as a Level 1 configuration. This is supported by Figure A3 which shows configuration E lay closer to the region of acceptable dropback than configurations A, C2 and D. In these three configurations (A, C2 and D), pilot comments were indicative of excessive dropback and pilot ratings were in the handling qualities Level 2 and 3 regions.

Configuration G.

A synopsis of pilot comments for aircraft configuration G is presented in the following paragraphs and Table 7.

Main comments of configuration G was that pilots found this to be a "good flying" configuration as reflected in the Cooper-Harper ratings. However, three of four pilots reported the configuration to be slightly sluggish, with control forces heavier than desired. Pilot 4 noted that quicker response might have made the task easier, with similar comments from Pilot 3. Pilot 2 described a mushiness or lagginess in response. No further deficiencies were noted. Pilot 1 found no deficiencies at all.

In the area of pilot performance, 6 out of 12 approaches met desired criteria, indicating the pilots may have had more trouble with this configuration than they themselves identified. However, no firm conclusions can be drawn since any number of reasons might account for these results. Though Pilot 1 failed to achieve even adequate criteria on one approach, this was on his first approach in the program when he was less familiar with the task. Pilot 4, again on his first evaluation of the program, attributed two adequate approaches to premature power reduction, though his angle of attack (AOA) on one of these was low (i.e., fast), perhaps indicating the configuration was in fact giving insufficient pitch response, or simply that he was still relatively unfamiliar with the task. Finally, some

Table 6
VARIABLE STABILITY SYSTEM CONFIGURATION E - SUMMARY OF RESULTS

Predicted Level:	CAP: 1	Bandwidth: 1	Bandwidth w/ Drb: 2
Dynamics:	ω_{sp}: 2.18 ζ_{sp}: 0.523	ω_{BW}: 2.8 τ_p: 0.079	τ_θ: 0.072
Pilot	Cooper-Harper Rating	PIO Rating	Workload Rating
1	---	---	---
2	2	2	1
3	2, 1	1, 1	2, 1
4	---	---	---

Notes: 1. CAP - control anticipation parameter
2. Drb - dropback
3 ω_{sp} - short period natural frequency
4. ζ_{sp} - short period damping ratio
5. ω_{BW} - bandwidth
6. τ_p - estimated phase delay
7. τ_θ - lower order equivalent system time delay
8. PIO - pilot-induced oscillation
9. --- not applicable

Table 7
VARIABLE STABILITY SYSTEM CONFIGURATION G - SUMMARY OF RESULTS

Predicted Level:	CAP: 1	Bandwidth: 1	Bandwidth w/ Drb: 2
Dynamics:	ω_{sp}: 2.50 ζ_{sp}: 0.785	ω_{BW}: 3.6 τ_p: 0.071	τ_θ: 0.078
Pilot	Cooper-Harper Rating	PIO Rating	Workload Rating
1	1	1	1
2	4	1	5
3	2	1	2
4	3	1	3

Notes: 1. CAP - control anticipation parameter
2. Drb - dropback
3 ω_{sp} - short period natural frequency
4. ζ_{sp} - short period damping ratio
5. ω_{BW} - bandwidth
6. τ_p - estimated phase delay
7. τ_θ - lower order equivalent system time delay
8. PIO - pilot-induced oscillation

doubt must be expressed as to the validity of Pilot 3's Cooper-Harper rating of 2. This rating was assigned after the pilot noted some sluggishness, commented on increased workload, and achieved only one desired criteria approach out of three.

A subsidiary comment by Pilot 2 was that despite the sluggishness, initial pitch response was good, indicating some discrepancy between initial and sustained response.

In additional analysis, the comments point to a low steady state pitch rate compared to the initial pitch rate—or a tendency towards excessive dropback. As in VSS configuration E, configuration G's dropback lay closer to the acceptable region as shown in Figure A3 and seems to have had less impact on pilot opinion than the greater dropback on configurations A, C2 and D. Given the task criteria achieved, dropback may have affected task performance more than the evaluation pilots realized.

Configuration H.

A synopsis of pilot comments for aircraft configuration H is presented in the following paragraphs and Table 8.

Regarding main comments, it was noted that this VSS configuration was graded as a Level 1 configuration with few deficiencies and overall good pilot comments.

In the area of pilot performance, seven out of nine approaches met desired landing criteria. One instance of adequate criteria being met was on Pilot 3's first evaluation of the program, when he was less familiar with the task. Overall, consistently good results were achieved in the landing task. The pilot's subsidiary comments on deficiencies were mixed—Pilot 1 felt the pitch response to be a little slow but with "good command authority," while Pilot 4 felt that it was too quick initially with

Table 8
VARIABLE STABILITY SYSTEM CONFIGURATION H - SUMMARY OF RESULTS

Predicted Level:	CAP: 1	Bandwidth: 2	Bandwidth w/ Drb: 2
Dynamics:	ω_{sp}: 2.29 ζ_{sp}: 0.967	ω_{BW}: 2.3	τ_p: 0.074 τ_θ: 0.070
Pilot	Cooper-Harper Rating	PIO Rating	Workload Rating
1	2	1	3
2	---	---	---
3	1	1	1
4	3	1	3

Notes: 1. CAP - control anticipation parameter
2. Drb - dropback
3 ω_{sp} - short period natural frequency
4. ζ_{sp} - short period damping ratio
5. ω_{BW} - bandwidth
6. τ_p - estimated phase delay
7. τ_θ - lower order equivalent system time delay
8. PIO - pilot-induced oscillation
9. --- not applicable

slightly slow steady-state response. Despite the apparent discrepancy here, the comments may in fact represent the same phenomenon: good initial pitch motion (or command authority) with slightly low sustained response. This again indicates excessive dropback, but as in configurations E and G the level of dropback encountered did not cause pilot opinion to drop below overall Level 1 ratings. It did, however, cause Pilots 1 and 4 to assign less than perfect Cooper-Harper ratings attributed directly to a "minor deficiency with pitch command rate" (Pilot 1) or because "the pitch response was mildly unpleasant" (Pilot 4). Pilot 3 felt there were no deficiencies. As seen in Figure A3, configuration H lay closest to the acceptable dropback region and is supported by the comments above.

Configuration I.

A synopsis of pilot comments for aircraft configuration I is presented in the following paragraphs and Table 9.

In the area of main comments, the principal comments on this configuration indicated the VSS configuration was sluggish, but with a disparity between initial pitch response (Pilot 1: "too quick," Pilot 2: "about right") and slower maneuver response (Pilot 1: "good AOA command," Pilot 2: "slow response for maneuver"). While this was identified by Pilots 1 and 2, Pilot 4's comments strongly stressed the sluggishness of maneuver response: "couldn't get the motion desired so had to pull more." Note, though Pilot 1 considered the maneuver response sufficient, stick forces were considered too high. Given the stick force gradient was the same for all VSS configurations tested, this may indicate that Pilot 1 too found the maneuver response too slow but did not identify it as such.

Regarding pilot performance, 8 out of 12 landings met desired criteria, showing degraded performance over other VSS configurations which were rated as Level 1, possibly as a result of the sluggish maneuver response. Pilot 4 particularly noted that in the flare he was "trying to let the aircraft down but couldn't get the nose down with smooth small motions."

In addition to the above comments, subsidiary comments of Pilots 1 and 4 included the comment that they noticed a pitch bobble. Pilot 4 found this only on the third landing and considered it easily compensated for, while Pilot 1 stated it was very distracting but did not compromise task performance. Pilot 2 did not identify this problem. It should be noted that Pilot 1's first evaluation of the configuration (also the first test point of the program) did not identify any of these deficiencies, but noted a tendency towards high angles of attack in the flare. This may have indicated a higher workload than Pilot 1 realized leading to poorer power and energy control.

In additional analysis, the pilot comments support the inference that this configuration had excessive dropback. This conclusion can be drawn from all pilots' comments more clearly than for some other VSS configurations where only one or two pilots noted characteristics associated with high dropback. This may indicate that pilots are sensitive to increasingly excessive dropback in this region.

Table 9
VARIABLE STABILITY SYSTEM CONFIGURATION I - SUMMARY OF RESULTS

Predicted Level:	CAP: 1	Bandwidth: 1	Bandwidth w/ Drb: 2
Dynamics:	ω_{sp}: 3.28 ζ_{sp}: 0.830	ω_{BW}: 3.0 τ_p: 0.071	τ_θ: 0.085
Pilot	Cooper-Harper Rating	PIO Rating	Workload Rating
1	4, 5	1, 2	3, 6
2	4	1	5
3	---	---	---
4	5	2	4

Notes: 1. CAP - control anticipation parameter
2. Drb - dropback
3 ω_{sp} - short period natural frequency
4. ζ_{sp} - short period damping ratio
5. ω_{BW} - bandwidth
6. τ_p - estimated phase delay
7. τ_θ - lower order equivalent system time delay
8. PIO - pilot-induced oscillation
9. --- not applicable

Configuration J.

A synopsis of pilot comments for aircraft configuration J is presented in the following paragraphs and Table 10.

The pilot's main comments were unanimous in identifying this VSS configuration as slow or sluggish. Pilot 1 reported he "ran out of pitch power in flare," while Pilot 4 stated he "could not get the nose authority I wanted."

The slow response in pilot performance gave just 4 desired criteria landings out of 12 approaches with both touchdown firmness and landing zone position responsible for this performance in roughly equal proportions. Pilot 4 reported touching down firm and fast due to the slow response using a variety of pilot techniques (high gain and low gain).

The subsidiary comments of the pilots included the following observations: Pilot 2 reported the slow aircraft response resulted in over control and slow oscillations about target pitch attitudes and during the offset correction to centerline, AOA excursions. These characteristics can be explained in terms of the slow pitch response—an input was made, the aircraft did not seem to respond and the size of the input was increased just as the pitch axis began to move, resulting in over control in pitch or AOA. Table 10 shows Pilot 2 gave this VSS configuration a Cooper-Harper rating of 4.5. Justification for this rating was the configuration required more than moderate compensation for desired performance; however, considerable compensation was not required to achieve adequate performance. Thus, the pilot felt a rating of 4.5 was the most accurate rating for this VSS configuration. Refer to Figure C2 for the Cooper-Harper Pilot Rating Scale.

Table 10
VARIABLE STABILITY SYSTEM CONFIGURATION J - SUMMARY OF RESULTS

Predicted Level:	CAP: 3	Bandwidth: 2	Bandwidth w/ Drb: 3
Dynamics:	ω_{sp}: 1.44 ζ_{sp}: 0.214	ω_{BW}: 1.7 τ_p: 0.078	τ_θ: 0.066
Pilot	Cooper-Harper Rating	PIO Rating	Workload Rating
1	6	1	5
2	4.5	3	6
3	---	---	---
4	5, 5	1,1	6, 4

Notes: 1. CAP - control anticipation parameter
2. Drb - dropback
3 ω_{sp} - short period natural frequency
4. ζ_{sp} - short period damping ratio
5. ω_{BW} - bandwidth
6. τ_p - estimated phase delay
7. τ_θ - lower order equivalent system time delay
8. PIO - pilot-induced oscillation
9. --- not applicable

Additional analysis, illustrated in Figure A3, showed that this configuration should have had excessive dropback. However, due to the slow time response the evaluation pilots were not able to break out the difference between the initial and steady state response. Thus, dropback did not appear to be a factor in pilot rating for this configuration as supported by the above comments.

Configuration K.

A synopsis of pilot comments for aircraft configuration K is presented in the following paragraphs and Table 11.

In the main comments, the overall assessment was that this configuration was slow or sluggish. Pilot 2 simply assessed the aircraft as sluggish with no further deficiencies. Pilots 1 and 4 noted some form of apparent delay (Pilot 1: "a small lag," Pilot 4: "response seemed to ramp up"). Pilot 3 commented in a different way on the same phenomenon stating that "small stick movements produced no movement of the nose." This comment may reflect the slow response of the configuration to initial inputs requiring an increase in stick movement from the pilot, which then appeared to generate the aircraft movement that was in fact the slow response from the initial input. However, from the LOES match, the configuration had an equivalent delay of 0.066 second, which was within MIL-STD-1797A recommendations for acceptable delay. Thus, the configuration's time delay did not necessarily explain pilot comments of sluggishness.

Regarding pilot performance in this configuration, both Pilots 3 and 4 reported using a technique comparable with lead compensation— an oversized initial input followed by a check in the opposite direction. Pilot 1 also described using lead compensation. Ten out of 19 approaches met desired criteria. Workload and pilot compensation required were the main factors in the assigned pilot ratings.

Pilots 1 and 3, in their subsidiary comments, remarked on some form of undesirable pitch motions. Pilot 1 directly assessed this as a tendency to overshoot desired pitch attitudes due to the larger inputs required to counter the slow aircraft response. It should also be noted that Pilot 4 assessed this configuration on three separate occasions and pilot ratings were somewhat inconsistent. On the first evaluation of this configuration, the pilot felt there was a deficiency, but was not able to identify it. Only the second look at the configuration (Cooper-Harper 2 assigned) was inconsistent with other pilot comments; on this, the pilot reports using a low gain technique.

In additional analysis, the safety pilot noted on Pilot 4's last evaluation of this configuration (Cooper-Harper 6 assigned) the pilot seemed more fatigued than usual. Thus, the pilot was either more aware of the compensation technique or was unable to compensate as well when fatigued. The safety pilot noted that Pilot 4 adopted a low gain technique—placing the aircraft close to desired parameters and then backing out of the loop and accepting what the aircraft gave him. Even though Pilot 4's Cooper-Harper ratings showed a wide range, it seems the pilot found a deficiency on one evaluation which he was better able to compensate for without noticing when less fatigued.

Table 11
VARIABLE STABILITY SYSTEM CONFIGURATION K - SUMMARY OF RESULTS

Predicted Level:	CAP:	Bandwidth: 2	Bandwidth w/ Drb: 3
Dynamics:	ω_{sp}: 1.44 ζ_{sp}: 0.555	ω_{BW}: 1.9 τ_p: 0.082	τ_θ: 0.066
Pilot	Cooper-Harper Rating	PIO Rating	Workload Rating
1	5	3	7
2	4	1	4
3	3	1	4
4	3, 2, 6	1, 1, 1	4, 2, 5

Notes: 1. CAP - control anticipation parameter
2. Drb - dropback
3 ω_{sp} - short period natural frequency
4. ζ_{sp} - short period damping ratio
5. ω_{BW} - bandwidth
6. τ_p - estimated phase delay
7. τ_θ - lower order equivalent system time delay
8. PIO - pilot-induced oscillation

Configuration P.

A synopsis of pilot comments for aircraft configuration P is presented in the following paragraphs and Table 12.

In the pilots' main comments, all pilots noted either a PIO (Pilots 1, 2 and 3) or pitch bobble (Pilot 4). This was stressed as a very strong tendency by Pilots 1, 2 and 3. Pilot 2 described the pitch axis as very sensitive—but at a low frequency of response. Pilots 1 and 3 also described the response as slow, with Pilot 1 reporting running out of "pitch command" in the flare. All pilots reported that aggressiveness exacerbated the PIO.

The result of this configuration on pilot performance was that workload was high, significant compensation being required in the form of smoothing (Pilots 1, 2 and 3) and "backing out of the loop" (Pilots 1 and 2). Pilot 4 reported using small quick inputs. Only six out of 16 landings met desired criteria due to both touchdown firmness and position.

In their subsidiary comments, Pilot 2 felt control was in question. Pilot 1 also felt control was in question on his first evaluation of the configuration, but not on his second. However, on this second evaluation a PIO of sufficient amplitude to trip the VSS was encountered.

High Frequency Trends (VSS Configurations A, C2, and D):

Pilot comments for the high frequency VSS configurations (A, C2, and D) included an initial quick response followed by a slow or sluggish steady-state response. The pitch attitude of the aircraft was sensitive while the flightpath was sluggish. Both of these comments characterized the VSS configurations as having excessive dropback. Applying the dropback definition to the VSS configurations predicted them to have excessive dropback.

Configuration C2 had more favorable pilot ratings than A and D, and was not considered as pitch sensitive. Pilots reported that the pitch oscillation in C2 could be damped out by pilot inputs, while for configurations A and D the oscillations were very difficult to avoid. In the CAP domain, this correlates to a low damping. In the bandwidth domain, both points satisfied the two criteria needed for the discontinuous jump—both were gain limited and had a non-monotonic gain pitch attitude to pitch manipulator Bode plots. Thus, their handling qualities should have been poor due to the "shelf" type Bode magnitude plots. In the dropback domain, the worse pilot ratings may be attributed to excessive dropback.

Table 12
VARIABLE STABILITY SYSTEM CONFIGURATION P - SUMMARY OF RESULTS

Predicted Level:	CAP: 1	Bandwidth: 2	Bandwidth w/ Drb: 3
Dynamics:	ω_{sp}: 1.20 ζ_{sp}: 0.435	ω_{BW}: 1.4 τ_p: 0.077	τ_θ: 0.066
Pilot	Cooper-Harper Rating	PIO Rating	Workload Rating
1	8, 6	5, 3	9, 5
2	8	4	6
3	5	4	5
4	7	2	not rated

Notes: 1. CAP - control anticipation parameter
2. Drb - dropback
3 ω_{sp} - short period natural frequency
4. ζ_{sp} - short period damping ratio
5. ω_{BW} - bandwidth
6. τ_p - estimated phase delay
7. τ_θ - lower order equivalent system time delay
8. PIO - pilot-induced oscillation

Using the mode of pilot ratings, or the pilot rating with the greatest frequency, the actual handling qualities levels are shown in Table 13. Note that all evaluation pilots agreed upon the aircraft handling qualities levels except for VSS configuration A (Appendix B). Four evaluations gave this configuration a Level 3 rating while one gave the configuration a Level 2 rating. Table 13 also shows the CAP, bandwidth, and bandwidth with dropback criteria results. Shaded blocks indicated where the predictive methods matched actual pilot opinion.

Table 13 shows CAP and bandwidth both matched the actual VSS configuration C2 handling qualities level. Applying the dropback definition to configuration C2 preserved the predictive Level 2 rating. Applying the dropback definition to VSS configurations A and D increased the predictive ratings to Level 2 which agreed with both the CAP and bandwidth metrics. However, the evaluation pilots felt those two configurations had Level 3 handling qualities. Thus, all methods underpredicted the actual handling qualities of configurations A and D.

In summary, the bandwidth criterion with and without applying the dropback criterion correctly matched pilot opinion of VSS configuration C2, or the high frequency point without a shelf-type Bode magnitude plot. The evaluation pilots gave Level 3 ratings to both VSS configurations A and D, which satisfied both jump conditions-being gain limited and having a non-monotonic Bode magnitude plot. Bandwidth with dropback incorrectly matched VSS configurations A and D. Thus, these flight test results indicate a shelf-type Bode plot, as in VSS configurations A and D, indicate Level 3 handling qualities rather than the magnitude of bandwidth. The VSS configurations A and D also had PIO tendencies. Both configurations had PIO ratings of 4, indicating the oscillations were not divergent. All evaluation pilots commented that each configuration had the tendency to pitch bobble or PIO as pilot aggressiveness increased. During landing 6.4, the variable stability system disengaged due to a growing oscillation. Time histories of stick deflection, aircraft attitude and angle of attack, stabilator position, and stabilator rate are presented in Appendix I. The PIO was encountered twice during the approach. The first encounter occurred just as the pilot aggressively corrected back to centerline during the lateral offset. A divergent PIO was not encountered during this maneuver since the pilot had enough altitude to back out of the loop and re-enter the loop slowly, as shown in the stick deflection plot in Figure I1.

The second instance where a PIO was encountered was during the flare, again shown in Figure I1. This time the pilot did not back out of the loop due to the close proximity of the ground. A divergent PIO was encountered and resulted in the approach being terminated when the VSS transferred control to the safety pilot. The PIO rating of 4 on this approach was a result of the extremely short time period of the PIO and the inability of the evaluation pilot to determine if the oscillation was divergent. It was not until postflight analysis that it was realized the oscillations were divergent.

Time traces of the left and right horizontal stabilators, refer to Figure I2, show the classical sawtooth form of a rate limit. Plotting the derivative of each stabilators' deflection versus time shows those areas where the stabilators were rate limited. As the surface reached the rate limit its derivative reached and remained at the maximum rate—approximately 70 degrees/second for VISTA. This is shown as a constant horizontal line on the derivative time traces. As shown in Figure I3, the first PIO did not result in rate limiting. Figure I4 shows the second PIO had 0.7 second of rate limiting

Table 13
HIGH FREQUENCY VARIABLE STABILITY SYSTEM (VSS)
CONFIGURATION HANDLING QUALITIES LEVELS

VSS Configuration	Mode of Actual Pilot Opinion	Predictive Metric		
		Control Anticipation Parameter	Bandwidth	Bandwidth With Dropback
A	3	2	2	2
D	3	2	2	2
C2	2	2	2	2

before the VSS transferred control to the safety pilot. However, the important point was the divergent nature of the PIO began before the stabilators were rate limited.

Mid-Frequency Trends (VSS Configurations E, G, H, and I):

The VSS configurations E, G, H, and I lay within the "heart" of both the CAP and bandwidth domains. All configurations were predicted to have excessive dropback. Pilot comments indicated that VSS configuration I clearly had excessive dropback while configurations G and H were in an area where excessive dropback was noticed by some but not all pilots. One evaluation pilot out of four for configuration G and one out of three for configuration H commented that initial nose movement was good while it was slow or sluggish in the steady-state response, thus indicating excessive dropback. As shown in Figure A3, configurations G and H lay closer to the proposed dropback line. Configuration E had no pilot comments which indicated excessive dropback despite the prediction of excessive dropback.

The mode of actual pilot opinion revealed trends among the predictive handling qualities criteria for these four configurations. The mode along with the predictive handling qualities are presented in Table 14. Shaded blocks indicate where the predictive methods matched actual pilot opinion. Generally, the evaluation pilots rated VSS configurations E, G, and H the best out of all evaluated VSS configurations stating the aircraft had good predictable initial and steady-state responses.

All evaluation pilots gave these four VSS configurations the same handling qualities rating except for Pilot 2 who gave configuration G a Level 2 rating while the three other pilots rated the configuration as Level 1. Justification for the Level 2 rating was due to the "slight mushiness/ lagginess" in the steady-state response. This caused the pilot to over control initial inputs and approach the AOA test limit of 13 degrees. To prevent these undesirable AOA excursions, the pilot was required to compensate by anticipating aircraft response.

As seen in Table 14, both the CAP and bandwidth criteria matched predicted pilot opinion for VSS configurations E and G. The evaluation pilots noticed excessive dropback on all configurations except VSS configuration E. However, applying the dropback definition to bandwidth resulted in a conservative prediction for configurations E, G, and H because of their excessive dropback. Thus, though the evaluation pilots noticed characteristics of excessive dropback their performance did not appear to be compromised. They felt these VSS configurations had good, well-defined, and predictable handling qualities. These comments also agreed with Figures D7 and D8 which show that application of the dropback criterion for CAP Level 1 aircraft decreased the theoretical area of agreement between the criteria. Thus, results indicate application of the dropback criterion to VSS configurations E, G, and H did not help predict pilot opinion.

Increasing ω_{sp} and ω_{BW} from configuration H to I, as shown in Figures A1 and A2, resulted in worse handling qualities. Because of the worse handling qualities and noticeable dropback, the dropback criterion should be applied to VSS configuration I. These results may indicate the dropback criterion should be applied to those aircraft which lay above VSS configuration H in the CAP domain. Results from this flight test are not sufficient enough to determine the exact location where dropback should be applied. However, results do indicate pilot opinion began to be influenced by excessive

Table 14
MID-FREQUENCY VARIABLE STABILITY SYSTEM (VSS) CONFIGURATION
HANDLING QUALITIES LEVELS

VSS Configuration	Mode of Actual Pilot Opinion	Predictive Metric		
		Control Anticipation Parameter	Bandwidth	Bandwidth With Dropback
E	1	1	1	2
G	1	1	1	2
H	1	1	2	2
I	2	1	1	2

dropback between an ω_{sp} of 2.3 and 3.3 radians per second and between a CAP value of 1.31 and 3.28/g*second^2.

Low Frequency Trends (VSS Configurations J, K, and P):

The VSS configurations J, K, and P lay in the lower frequency range of CAP as shown in Figure A1. These points had low bandwidths, lying to the left of the bandwidth Level 1 region shown in Figure A2.

Configuration K lay between a Level 1 and 2 aircraft; three evaluations rated the configuration Level 1, while three rated the configuration Level 2. All evaluation pilots gave the configuration a PIO rating of 1 except Pilot 1 who gave the configuration a PIO rating of 3, meaning undesirable motions compromised task performance. The PIO rating of 3 was assigned because of undesirable pitch motions. These motions were due to large, fast control inputs required to compensate for the slow pitch response.

Pilot 4 flew the configuration three times assigning Cooper-Harper ratings of 3, 2 and 6. He flew this configuration during the sixth evaluation on his first sortie and during the second and fifth evaluations one his second sortie. During the first evaluation Pilot 4 commented, "There was something I didn't like, but couldn't put my finger on it." During the second evaluation he commented the configuration had a good initial predictable response. During the third evaluation he commented the configuration was slow initially and then would ramp up to a quick steady-state. This unpredictably required extensive pilot compensation that required improvement. The safety pilot noted Pilot 4 seemed more fatigued during the third evaluation and that he changed his compensation techniques between the second and third evaluations. The safety pilot stated that during the first landing of the third evaluation Pilot 4 was in a PIO reaching 14 degrees angle of attack. After this landing, Pilot 4 changed his technique and quit flaring the aircraft and began to accept harder landings. Thus, it seemed that Pilot 4 found what it was that he did not like during the first evaluation.

Decreasing the damping ratio from VSS configuration K to J resulted in a solid Level 2 rating by the evaluation pilots. Pilot comments indicated the decrease in pilot opinion resulted from the slow response and resulting over control and pitch overshoots. This over control led to AOA excursions during the initial offset correction. As a result the evaluation pilots had harder touchdowns because of a lack of pitch response in the flare. As shown in Table 15, bandwidth matched pilot opinion for VSS configurations K and J. Pilot comments did not indicate excessive dropback. Because of the configurations' slow time response, the evaluation pilots did not notice excessive dropback even though application of the dropback definition predicted excessive dropback.

Decreasing the short period frequency from VSS configuration K to P resulted in a decrease in the mode of pilot opinion rating to Level 3. Two evaluation pilots rated configuration P as a Level 2 aircraft even though pilot compensation was high and the aircraft had the tendency to PIO. The PIO ratings ranged from 2 to 5 for configuration P. Pilot comments did not indicate excessive dropback. Once again, the configuration's time response was too slow for pilots to judge the total response. Pilot comments centered around the configuration's very slow response and tendency to overshoot, resulting in PIOs. Pilot aggressiveness was a factor in the amplitude of PIOs. Compensation techniques were to

Table 15
LOW FREQUENCY VARIABLE STABILITY SYSTEM
CONFIGURATION HANDLING QUALITIES LEVELS

Control Anticipation Parameter	Mode of Actual Pilot Opinion	Predictive Metric: Control Anticipation Parameter	Predictive Metric: Bandwidth	Predictive Metric: Bandwidth With Dropback
K	1, 2	1	2	3
P	3	1	2	3
J	2	3	2	3

back out of the loop allowing the aircraft to fly itself down the glideslope as much as possible. Applying the dropback definition to configuration P resulted in a correct match. However, this match was due to the wrong reasons. The evaluation pilots did not notice excessive dropback for this configuration, thus the definition should not be applied.

In summary, VSS configuration K was a borderline Level 1, Level 2 configuration. Decreasing the damping from K to J resulted in a clearly Level 2 aircraft. Although configuration J had excessive dropback, it was not noticed due to the slow response of the configuration. Decreasing the short period frequency from K to P resulted in three ratings as a Level 3 aircraft and two ratings as a Level 2 aircraft. However, all evaluation pilots commented on the susceptibility of a PIO during the maneuver.

Overall, the CAP and bandwidth criteria had a 50 percent prediction correlation on the actual pilot's statistical mode while bandwidth with dropback had a 30 percent prediction accuracy as shown Table 16. When CAP and bandwidth with dropback agreed or bandwidth and bandwidth with dropback agreed, there was a 25 percent prediction correlation on the pilot's statistical mode. When CAP agreed with bandwidth there was a 50 percent prediction correlation.

For the high frequency configurations (A, C2, and D), all predictive methods agreed however only configuration C2's prediction matched pilot opinion. The CAP and bandwidth predictions agreed for the mid-frequency configurations (E, G, and I). Actual pilot comments indicated only configurations E and G matched predictions. The CAP and bandwidth predictions for configuration I agreed but bandwidth with dropback matched pilot opinion. Bandwidth and bandwidth with dropback predictions agreed for configuration H but CAP matched pilot opinion. For the low frequency VSS configuration J, CAP and bandwidth with dropback predictions agreed, however, bandwidth matched pilot opinion. Bandwidth with dropback incorrectly predicted pilot opinion because it predicted excessive dropback when pilot comments did not support excessive dropback.

Table 16
VARIABLE STABILITY SYSTEM (VSS)
CONFIGURATION HANDLING QUALITIES LEVELS SUMMARY

VSS Configuration	Mode of Actual Pilot Opinion	Predictive Metric			
		CAP	Bandwidth	Bandwidth With Dropback	Bandwidth With Modified Dropback[1]
A	3	2	2	2	2
C2	2	2	2	2	2
D	3	2	2	2	2
E	1	1	1	2	1
G	1	1	1	2	1
H	1	1	2	2	1
I	2	1	1	2	2
J	2	3	2	3	2
K	1, 2	1	2	3	2
P	3	1	2	3	2

Note: CAP - control anticipation parameter

[1]Bandwidth with modified dropback uses the proposed definition of bandwidth and applied the dropback definition only for VSS configurations which had a short period natural frequency greater than or equal to configuration I.

After defining bandwidth with modified dropback as in Table 16, Note 1, the predictive metrics matched the following statistical mode of pilot ratings:

CAP - 50 percent correlation

Bandwidth - 50 percent correlation

Bandwidth with modified dropback - 70 percent correlation.

When CAP agreed with bandwidth with modified dropback there was a 67 percent prediction correlation. When bandwidth agreed with bandwidth with modified dropback there was a 63 percent prediction correlation. Using the modified dropback, all predictive metrics agreed and matched pilot opinion for VSS configurations E and G. Configuration H was matched by CAP and bandwidth with modified dropback. Bandwidth with modified dropback was the only metric which matched pilot opinion for configuration I. Both bandwidth and bandwidth with modified dropback predictions agreed and matched pilot opinion for configurations J and K.

As shown in Figure A2, VSS configuration H lay between the current bandwidth Level 1 boundary and the proposed bandwidth Level 1 boundary. If the modified dropback definition is applied, then configuration H is predicted to be Level 1 by bandwidth with modified dropback. Thus, this configuration supports the location of the proposed boundary. Decreasing the bandwidth to configuration K crosses the proposed boundary to just the other side and agrees with pilot opinion as being a Level 1, Level 2 configuration. Thus, flight test results support the location of the proposed bandwidth with dropback Level 1 boundary.

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CONCLUSIONS

Information regarding pilot opinion trends across a widely varied array of variable stability system (VSS) configurations and predicted handling qualities was gathered from this first flight test using the Variable-Stability In-Flight Simulator Test Aircraft (VISTA) NF-16D aircraft. The overall test objective was to evaluate discrepancies between the control anticipation parameter (CAP) and the bandwidth criteria with and without incorporating a proposed dropback criterion. However, due to the limitations of VISTA to accurately model specified short period frequency and damping parameters, test objectives 2 and 4 were only partially fulfilled and test objective 3 was not met. Despite this limitation, objectives were met in the areas of agreement and disagreement (objective 1), pilot opinion trends (objective 2), and the collection of supporting data (objective 6).

Pilot opinion of the high frequency VSS configurations (A, C2 and D) were influenced by excessive dropback. Pilot comments characterized these configurations as having an initial quick response followed by a slow and sluggish steady-state response. Additionally, pilot comments stated the pitch attitude of the configurations was sensitive while the flight path was considered sluggish. Pilot comments also indicated these configurations were not predictable. Collectively, these indicators of excessive dropback were the primary factors contributing to the Level 2 and Level 3 Cooper-Harper ratings.

Pilot comments in regard to mid frequency VSS configurations (E, G, H and I) indicate the handling qualities were well defined and predictable. However, it was within this region that pilot indicated the first signs of excessive dropback and its relative influence on the handling qualities of the configuration.

Pilot comments did not indicate excessive dropback for the low frequency configurations (J, K, and P) although the dropback definition predicted excessive dropback. Comments suggested the decrease in pilot opinion resulted from the slow response and resulting over control and pitch overshoots. This over control led to angle of attack excursions during the initial offset correction. As a result, the evaluation pilots had harder touchdowns because of a lack of pitch response in the flare.

During this test both the CAP criterion and the bandwidth criterion matched actual pilot opinion approximately 50 percent of the time. Incorporating the current definition of dropback to the bandwidth criterion decreased the prediction accuracy to approximately 30 percent.

However, flight test results indicate that excessive dropback may influence pilot opinion only at relatively high values of CAP or short period natural frequencies (ω_{sp}). All of the VSS configurations tested were determined to have excessive dropback. Results from flight test indicated there was a short period natural frequency or CAP value where excessive dropback began to influence pilot compensation techniques resulting in worse handling qualities. Results from this flight test are not sufficient enough to determine the exact location where dropback should be applied. However, results do indicate pilot opinion began being influenced by excessive dropback between an ω_{sp} of 2.3 and 3.3 radians per second and between a CAP value of 1.31 and 3.28/g*second^2. Pilot opinion was not influence by excessive dropback at lower ω_{sp} or CAP values due to the relatively slow response. Thus applying the dropback definition to the bandwidth criterion in those regions where pilot opinion was influenced by excessive dropback increased the prediction correlation to approximately 70 percent.

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APPENDIX A

TEST POINT MATRIX

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Table A1

SUMMARY OF FLIGHT TEST RESULTS FOR EACH VSS CONFIGURATION

Aircraft Configuration	Lower Order Equivalent System ω_{sp} (rad/sec^2)	ζ_{sp}	τ_θ (sec)	CAP [1/(g*sec^2)]	ω_{BWg} (rad/sec^2)	ω_{BWp} (rad/sec^2)	ω_{BW} (rad/sec^2)	τ_p (sec)
A	5.68	0.384	0.040	8.05	7.8	7.9	7.8	0.079
C2	4.97	0.632	0.075	6.16	6.7	6.8	6.7	0.084
D	5.40	0.290	0.080	7.27	6.1	6.1	6.1	0.077
E	2.18	0.523	0.072	1.19	3.8	2.8	2.8	0.079
G	2.50	0.785	0.078	1.56	5.2	3.6	3.6	0.071
H	2.29	0.967	0.070	1.31	2.3	3.8	2.3	0.074
I	3.28	0.830	0.085	2.68	3.0	5.1	3.0	0.071
J	1.44	0.214	0.066	0.52	2.1	1.7	1.7	0.078
K	1.44	0.555	0.066	0.52	3.2	1.4	1.9	0.082
P	1.20	0.435	0.066	0.36	2.4	1.4	1.4	0.077

Notes:
1. VSS - variable stability system
2. ω_{sp} - short period natural frequency
3. ζ_{sp} - short period damping ratio
4. CAP - control anticipation parameter
5. τ_θ - lower order equivalent system time delay
6. ω_{BWg} - gain limited bandwidth
7. ω_{BWp} - phase limited bandwidth
8. ω_{BW} - bandwidth
9. τ_p - phase delay

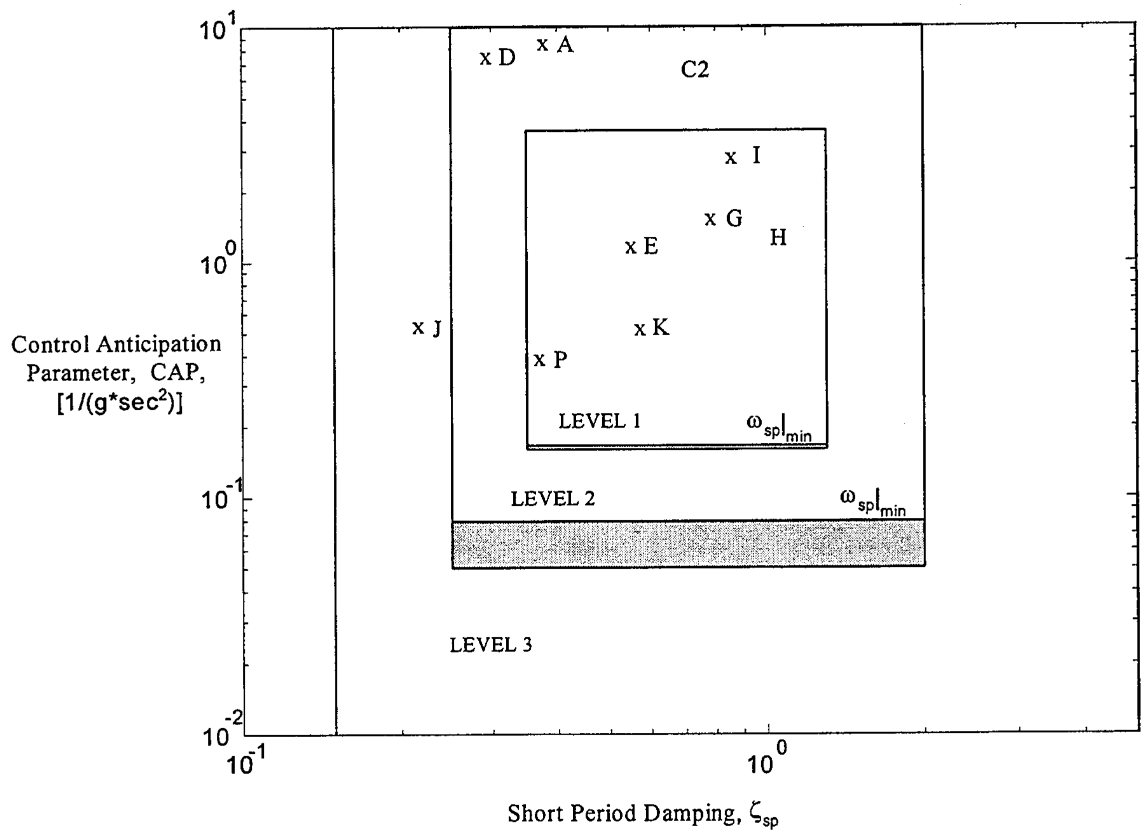

Figure A1 Test Results Plotted Using the CAP Criterion From MIL-STD-1797A ($1/T_{\Theta_2}$ = 0.45, n/α = 4.01)

Table A2
TABULAR RESULTS PLOTTED USING THE CAP CRITERION FROM MIL-STD-1797A ($1/T_{\Theta_2} = 0.45$, $n/\alpha = 4.01$)

Aircraft Configuration	Cooper-Harper Rating Levels	
	Predicted	Flight Test (based on statistical mode)
A	2	3
C2	2	2
D	2	3
E	1	1
G	1	1
H	1	1
I	1	2
J	3	2
K	1	1,2
P	1	3

Notes: 1. CAP - control anticipation parameter
2. T_{Θ_2} - lower order equivalent system time delay
3. n/α - change in normal load factor due to a change in angle of attack

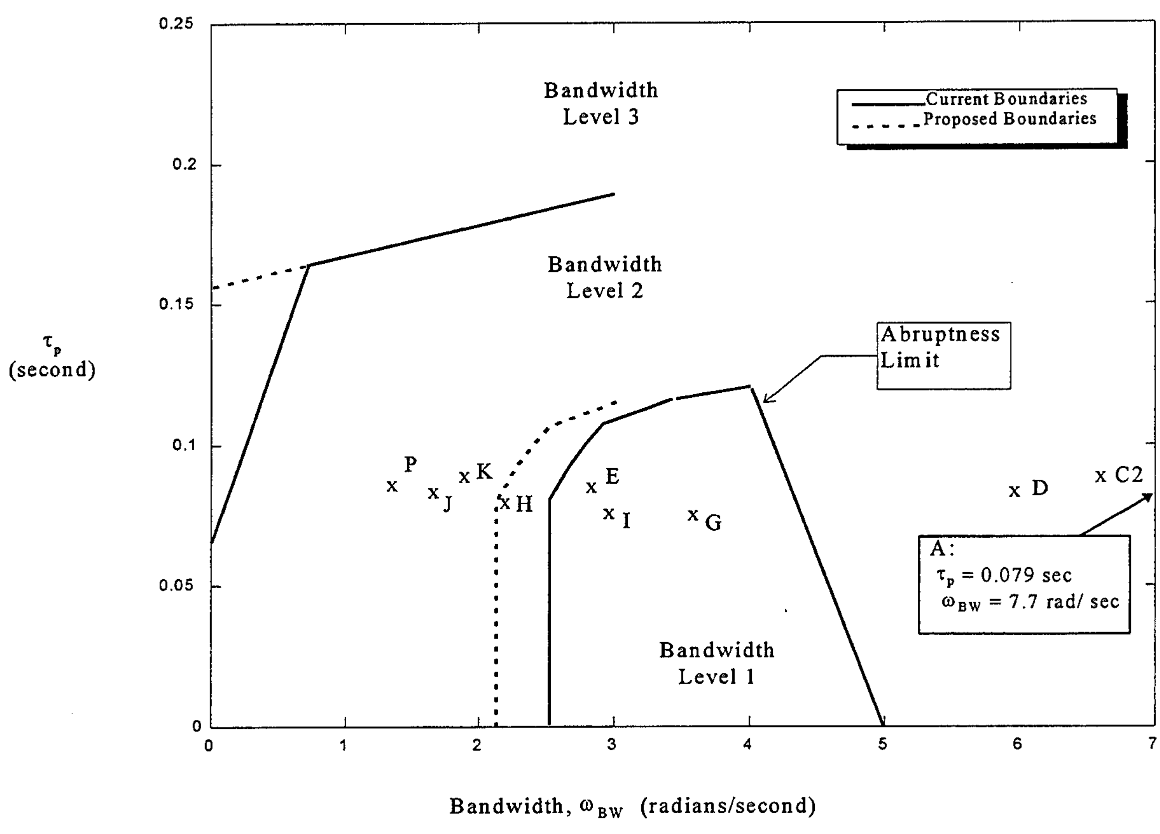

Figure A2 Test Results Using Bandwidth Criterion From MIL-STD-1797A and Proposed Bandwidth With Dropback Criterion

Table A3
TABULAR RESULTS USING BANDWIDTH CRITERION FROM MIL-STD-1797A
AND PROPOSED BANDWIDTH WITH DROPBACK CRITERION

Aircraft Configuration	Cooper-Harper Rating Levels		
	Predicted		Flight Test (based on statistical mode)
	Without Dropback	With Dropback	
A	2	2	3
C2	2	2	2
D	2	2	3
E	1	2	1
G	1	2	1
H	2	2	1
I	1	2	2
J	2	3	2
K	2	3	1,2
P	2	3	3

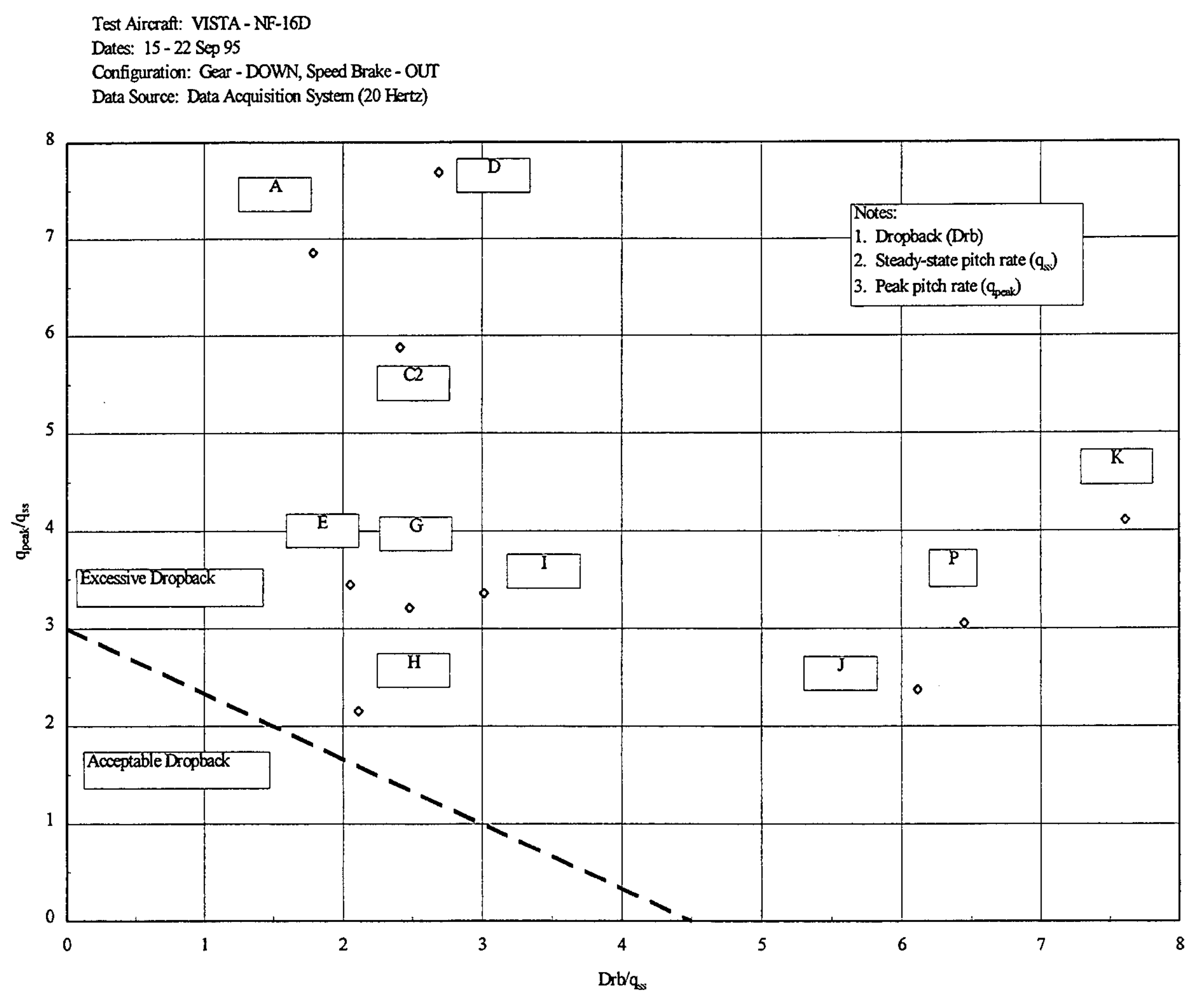

Figure A3 VSS Configuration Dropback Locations

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APPENDIX B

PILOT COMMENT DATABASE SUMMARIES

(Note: Appendix B contains, in its entirety, the Variable Stability System Configuration Flight Test Summary Report and the Handling Qualities Level Prediction Correlation Summaries.)

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Have CAP VSS Configuration Flight Test Summary Report

06-Dec-95

Configuration ID — **A**

Priority: 1 | **Actual SP Frequency:** 5.68 | **Actual SP Damping Ratio:** 0.38

Actual BW frequency: 7.8 | **Tau P:** 0.08

Predicted FQ Levels: **CAP:** 2 **BW:** 2 **BW with DB:** 3

3.4 **Mission date:** 15-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: None.

Feel system: Extremely sensitive. Just actuating the trim button caused a pitch bobble. Had to smooth inputs. Very springy stick, like it's attached to a really tight bungee. If the stick was pulled back and released it seems like it would smack into the instrument panel.

Handling qualities: Pitch is ratchety and jittery. Nose tracks in really small, high-frequency motions around the desired attitude. In any other operational aircraft (i.e. if this weren't a test), I'd suspect a major flight control malfunction.

Landing: Pitch sensitivity not too noticeable in flare. Light turbulence in the flare caused the nose to jiggle around.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	3,750	161	11	Light	220/6	☐
2	Desired	Soft	Desired	3,500	160	11	Light	220/6	☐
3	Desired	Soft	Desired	3,250	159	11	Light	240/7	☐

Cooper-Harper Rating: 7 **Notes on C-H:** High workload, deficiencies require improvement.

Workload Rating: 7 **PIO Rating:** 4

Recommendations: None

4.4 **Mission date:** 16-Sep-95 **Eval pilot:** (#2) Flt. Lt. Justin Paines

Setup: 1st & 2nd: 1 dot high at MP. 3rd 1/2 dot high.

Feel system: High forces for maneuver.

Handling qualities: Plenty of trimming required. Initial pitch sensitivity/bobble. Longer term response very, very slow - large inputs required - non linear, not predictable. Aggressiveness only slightly exacerbates bobble/ pitch sensitivity. Smooth-small initial/large sustained control inputs required (lag compensation).

Landing: None

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Go-Around	N/A	Neither	3,600			None	200/7	☐
2	Neither	Soft	Neither	3,300	150	11	None	190/9	☐
3	Adequate	Soft	Adequate	3,000	150	12	None	210/9	☐

Cooper-Harper Rating: 7 **Notes on C-H:** Workload intolerably high.

Workload Rating: 8 **PIO Rating:** 4

Recommendations: None

5.5 **Mission date:** 16-Sep-95 **Eval pilot:** (#3) Capt. Mark Schaible

Setup: None.

Feel system: Feel system good, but harmony was bad due to higher long. stick forces.

Handling qualities: Aircraft exhibited a motion that was a cross between a pitch bobble and a PIO. The stick seemed to be very sensitive but the aircraft flight path did not respond rapidly. The motion was hard to predict and hard to compensate for. The motion was felt more in the seat of the pants than noticed in any attitude change. Pitch bobble forced a great deal of concentration in the flare, if you let it get away from you, it would be difficult to compensate for. Aggressiveness aggravated the motions. Pilot had to be tight in the loop with small inputs to achieve desired criteria. Turbulence definitely made the A/C harder to control.

Landing: None.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Go-Around	N/A	Neither	3,200			Light	230/16G2	☒ unknown
2	Go-Around	N/A	Neither	3,100			Light	240/16G2	☒ Tail hardover
3	Desired	Soft	Desired	2,900	156	11	Light	220/16G2	☐
4	Adequate	Soft	Adequate	2,600	152	11	Light	240/18G2	☐

Cooper-Harper Rating: 6 **Notes on C-H:** Workload intolerably high.

Workload Rating: 8 **PIO Rating:** 4

Recommendations: None

6.4 **Mission date:** 17-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: Small, qiuck pitch oscillation noted as soon as I took control.

Feel system: None.

Handling qualities: Quick response. Small quick PIO there almost constantly. Still possible to get performance with the bobble, but it was constantly there. The pitch seemed sensitive, or touchy.

Landing: Extemely high worlkoad - Stopped breathing in the flare - extreme compesation in the smoothing technique (backing off, lowering the gains). Aggressiveness did affect the task with greater tendency to PIO. Go-around because PIO inceased in amplitude.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Medium	Adequate	4,000	157	11	None	230/11	☐
2	Go-Around	N/A	Neither	3,800			None	230/11	☒ Tail Limit, Safety Pi
3	Desired	Medium	Adequate	3,600	163	10	None	230/12	☐

Cooper-Harper Rating: 8 **Notes on C-H:** The go-around showed a possible divergent PIO putting controllability in question. The workload was extremely high because of the high pilot compensation. The configuration has major deficiencies.

Workload Rating: 8 **PIO Rating:** 4

Recommendations: None

8.3 **Mission date:** 18-Sep-95 **Eval pilot:** (#2) Flt. Lt. Justin Paines

Setup: Excellent setups

Feel system: Initial sensitivity (very touchy) but high forces for sustained/steady state maneuver.

Handling qualities: Touchy - pitch bobble (high frequency/low amplitutde) even with small inputs - difficult to avoid. Strong tendency to stay out of loop to avoid aggravating pitch oscillations in flare (resulting in first approach "neither" performance). While initial response was very sensitive and twitchy, sustained reponse was sluggish - not linear. In other words, the aircraft did not react quickly enough to control inputs to easily give desired performance, but the pitch sensitivity prevented a higher gain or any lead compensation in the inputs. Considerable smoothing of inputs / lag-lead compensation with slow build up to increased size of control input to overcome sluggish sustained response. Performance not consistent. However, while the oscillations were easy to excite with all but the smoothest control, once excited further aggressiveness did not exacerbate them - they were non-divergent.

Landing: None.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Neither	Soft	Neither	4,900	150	11	None	070/6	☐
2	Desired	Soft	Desired	4,600	159	12	None	110/3	☐
3	Desired	Soft	Desired	4,400	161	10	None	130/8	☐

Cooper-Harper Rating: 7 **Notes on C-H:** Workload intolerably high.

Workload Rating: 8 **PIO Rating:** 4

Recommendations: None

Configuration ID

C2

Priority: 3

Actual SP Frequency: 4.97 **Actual SP Damping Ratio:** 0.63

Actual BW frequency: 6.7 **Tau P:** 0.08

Predicted FQ Levels: **CAP:** 2 **BW:** 2 **BW with DB:** 2

3.6 **Mission date:** 15-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: None.

Feel system: Pitch axis is jittery and bouncy. Stick forces really high and require lost of trimming. Stick on a tight, notchy bungee. Displacement is slightly large. Friction and breakout are a bit high.

Handling qualities: Low.frequency pitch bobble, excursions small but sloppy and controllable. Motions damped okay. Response time is good in pitch, but tends to overshoot. Aggressiveness causes a pitch ratchet, pitch rate is not constant. PIO tendency is not divergent. Control harmony in offset is poor due to pitch overshoots and requirement for small inputs to prevent excursions.

Landing: Control in the flare is pretty good, mild pitch bobble encountered. Not too touchy in flare. Feels like stepping down a staircase as the roundout/flare are initiated.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	2,100	155	11	None	240/10	☐
2	Desired	Soft	Desired	1,700	155	11	Light	220/12	☐
3	Desired	Soft	Desired	1,500	152	11	None	220/14	☐

Cooper-Harper Rating: 6 **Notes on C-H:** Objectionable but tolerable deficiencies.

Workload Rating: 5 **PIO Rating:** 4

Recommendations: None

5.4 **Mission date:** 16-Sep-95 **Eval pilot:** (#3) Capt. Mark Schaible

Setup: None.

Feel system: Stick is extremely sensitive to inputs. Can only use fingertips to fly. No control harmony due to diffrence in lateral and longitudinal forces. Not enough stick movement to determine linearity.

Handling qualities: Very nervous aircraft. Nose is continually darting up and down. Can't place nose where you want it and aircraft feels like a spring board. Have to think way ahead of the A/C to anticipate requirements because if you need it now you won't get it.

Landing: On last landing, every time I tried to get in the loop to land, the A/C would get squirelly and force me out of the loop, so I had to accept a long landing.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	4,200	162	11	Light	240/18G2	☐
2	Desired	Soft	Desired	3,900	163	11	Light	230/17G2	☐
3	Neither	Soft	Neither	3,600	165	11	Light	230/16G2	☐

Cooper-Harper Rating: 6 **Notes on C-H:** Major deficiencies.

Workload Rating: 8 **PIO Rating:** 3

Recommendations: None

10.2 **Mission date:** 19-Sep-95 **Eval pilot:** (#3) Capt. Mark Schaible

Setup: None.

Feel system: Longitudinal forces were no where near in harmony with the lateral. Longitudinal required fingertip inputs or it would aggravate the undesireable motions.

Handling qualities: Nervous aircraft, intial response is too quick and unpredictable. Can't be to aggressive with the aircraft because it forces you to back out of the loop. On roundout for the flare you go to smoothly apply an input to flare and the aircraft gives you more than you wanted and doesn't allow you to pick the spot you want to put the aircraft down on. It could not be described as a PIO but more like a bobble type effect. The motion could be damped with the pilot in the loop and could be compensated for by anticipating future requirements in the flare (think way ahead of aircraft). Aircraft was more sensitive to turbulence.

Landing: None.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	2,800	156	11	None	010/3	☐
2	Desired	Medium	Adequate	2,500	157	11	None	Calm	☐
3	Desired	Soft	Desired	2,200	154	11	None	Calm	☐

Cooper-Harper Rating: 4 **Notes on C-H:** Flying qualities and workload drove my ratings.

Workload Rating: 4 **PIO Rating:** 3

Recommendations: None

Configuration ID **Priority:** 1 **Actual SP Frequency:** 5.4 **Actual SP Damping Ratio:** 0.03

D **Actual BW frequency:** 6.1 **Tau P:** 0.08

Predicted FQ Levels: **CAP:** 2 **BW:** 2 **BW with DB:** 2

4.3 **Mission date:** 16-Sep-95 **Eval pilot:** (#2) Flt. Lt. Justin Paines

Setup: Last 2 approaches 1 dot high at maneuver

Feel system: Light and sensitive for initial pitch repsonse, too heavy for long term response.

Handling qualities: Pitch bobble/sensitivity - very difficult to prevent this with normal inputs. Initial response quick/sensitive, longer term response slow. Non-linear - small inputs made because of the pitch sensitivity result in insufficient inputs for desired maneuver - the a/c doesn't give you what you expect. Didn't feel predictable. Aggressiveness makes pitch sensitivity/PIO worse - lots of smoothing of inputs required. However, no cliffs or divergent PIO apparent. In final stages of flare, pilot backs further out of loop and pitch bobble stops due to discomfort of bobble when close to ground - inputs here very open loop thus degrading tight a/c control and degrading task performance. Compensation required: smoothing of initial inputs followed by stronger sustained inputs for maneuver (lag), backing out of loop to prevent bobble/PIO.

Landing: Pitch bobble stops as pilot appears to come out of the loop in anticipation of touchdown.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	4,600	157	12	None	210/7	☐
2	Desired	Soft	Desired	4,300	153	11	None	200/8	☐
3	Neither	Soft	Neither	4,000	153	10	None	210/7	☐

Cooper-Harper Rating: 8 **Notes on C-H:** Controllability in question without compensation.

Workload Rating: 7 **PIO Rating:** 4

Recommendations: None

7.2 **Mission date:** 17-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: None.

Feel system: Very sensitive in pitch axis. Stick so sensitive that actuating the trim button caused undesirable pitch bobbles. Stick is very tight and feels like it's attached with a strong rubber bungee. Heavy stick forces during offset maneuvering. No freeplay at all, displacement too low. Requires lots of trimming to keep stick forces reasonable.

Handling qualities: Pitch bobble requires a lot of concentration, other parts of crosscheck fall out. Pitch response is too quick. Nose bounced around quite a bit with every little input, but still controllable and predictable. High frequency, low amplitude bobble. Entering the loop tighter causes more bobbles. Smoothing inputs and keeping them small and not abrupt. Devoting lots of attention to pitch control.

Landing: Forces get heavy in the flare but still able to control landing point well. Speed stability noticeable but forces increase quickly. Backed out of the loop to keep nose motions down to a minimum.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Medium	Adequate	6,000	160	11	Light	210/12	☐
2	Desired	Soft	Desired	5,800	163	11	None	240/12G1	☐
3	Desired	Soft	Desired	5,500	166	11	None	230/14G1	☐

Cooper-Harper Rating: 7 **Notes on C-H:** Pilot compensation too high, major deficiencies.

Workload Rating: 7 **PIO Rating:** 4

Recommendations: None

8.4 **Mission date:** 18-Sep-95 **Eval pilot:** (#2) Flt. Lt. Justin Paines

Setup: Excellent setups

Feel system: Non-linear - too light for initial pitch response, too heavy for sustained.

Handling qualities: Twitchy and pitch sensitive - but not excited just by resting hand on stick, only by deliberate control inputs - low amplitude high frequency pitch oscillations. Subsequent sluggishness in sustained repsonse - nonlinear. Sluggish response resulted in inadequate response for easy achievement of desired performance. Compensation: smoothing and lag to reduce excitation of pitch oscillations followed by increased size of input to compensate for sluggish response (lag-lead). Overshoot and high alpha excursion on lateral offset correction due to sluggish response. However, while the oscillations were easy to excite, once excited further aggressiveness did not exacerbate them - they were non-divergent. Note: as compared to the last configuration (test point 8.3), since many of my comments (and the ratings below) are similar, this configuration (8.4) was not as bad in the high frequency pitch sensitivity/oscillations (not as twitchy), but was as bad or worse in the sluggishness of sustained maneuver response.

Landing: None.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	4,000	160	10	None	330/5	☐
2	Desired	Soft	Desired	3,700	150	11	None	040/6	☐
3	Adequate	Soft	Adequate	3,400	160	10	None	050/6	☐

Cooper-Harper Rating: 7 **Notes on C-H:** Workload intolerably high.

Workload Rating: 7 **PIO Rating:** 4

Recommendations: None

9.3 **Mission date:** 18-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: Small medium rate pitch oscillation noted with the pilot in the loop. With forward pressure the oscillations were dampened easily. With aft stick the oscillations were more prevalent.

Feel system: None.

Handling qualities: Aggressiveness inceased the amplitude of the pitch bobble, but backing off the gain would quickly smooth it out. Out of phase... seemed like a possible time delay or slow initail input followed by a quick steady state. Able to get 180 out of phase with a quick pitch input. Slightly sensitive, but motions were predictable.

Landing: Smoothing inputs were more open loop to arrest the PIO. PIO noticed more during aggressive maneuvers like the roundout, while the flare still had some but they were lower amplitude. It was slightly sensitive but improved when backing off the gain.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Medium	Adequate	4,100	165	11	None	010/5	☐
2	Desired	Soft	Desired	3,700	157	11	None	Calm	☐
3	Adequate	Soft	Adequate	0	164	10	None	350/4	☐

Cooper-Harper Rating: 7 **Notes on C-H:** Worload was high and the deficiencies require improvement. Controllability was not in question.

Workload Rating: 7 **PIO Rating:** 4

Recommendations: None

Configuration ID

E

Priority: 1

Actual SP Frequency: 2.18 **Actual SP Damping Ratio:** 0.52

Actual BW frequency: 2.8 **Tau P:** 0.08

Predicted FQ Levels: **CAP:** 1 **BW:** 1 **BW with DB:** 2

4.1 **Mission date:** 16-Sep-95 **Eval pilot:** (#2) Flt. Lt. Justin Paines

Setup: Excellent

Feel system: Good

Handling qualities: Good, smooth control. Small pitch bobble noted encouraging minimal smoothing of inputs. Predictable, good response both initial and long term. High gain control no problem -aggressiveness does not effect HQ.

Landing: None

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Soft	Adequate	6,800	170	11	None	200/5	☐
2	Desired	Medium	Adequate	6,500	160	12	None	200/5	☐
3	Desired	Soft	Desired	6,000	160	11	None	210/6	☐

Cooper-Harper Rating: 2 **Notes on C-H:** Very slight pitch bobble noted on a couple of approaches

Workload Rating: 1 **PIO Rating:** 2

Recommendations: None

5.6 **Mission date:** 16-Sep-95 **Eval pilot:** (#3) Capt. Mark Schaible

Setup: None.

Feel system: Good, control harmony good.

Handling qualities: Very good handling characteristics. Pitch was slightly sluggish (not as crisp as I would like) but not objectionable. Overall good A/C.

Landing: Touchdown on first landing occurred at the same moment IP tripped off system. Should not affect rating.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	2,300	147	13	Light	230/17G2	☒ AOA limit
2	Desired	Soft	Desired	2,100	155	10	Light	220/19G2	☐
3	Desired	Soft	Desired	1,900	155	11	Light	220/17G2	☐

Cooper-Harper Rating: 2 **Notes on C-H:**

Workload Rating: 2 **PIO Rating:** 1

Recommendations: None

10.3 **Mission date:** 19-Sep-95 **Eval pilot:** (#3) Capt. Mark Schaible

Setup: None.

Feel system: Very good, no problems noted.

Handling qualities: Found no identifiable HQ deficiencies with this aircraft.

Landing: Last two landings I tried to land just after the desired entry box line to drive up gains, unfortunately, I landed about 5-10 feet short on my last two landings.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	1,900	156	11	None	010/5	☐
2	Adequate	Soft	Adequate	1,700	153	11	None	340/5	☐
3	Adequate	Soft	Adequate	1,400	153	11	None	360/3	☐

Cooper-Harper Rating: 1 **Notes on C-H:** No workload.

Workload Rating: 1 **PIO Rating:** 1

Recommendations: None

Configuration ID

Priority: 1 **Actual SP Frequency:** 2.5 **Actual SP Damping Ratio:** 0.79

G

Actual BW frequency: 3.6 **Tau P:** 0.07

Predicted FQ Levels: **CAP:** 1 **BW:** 1 **BW with DB:** 1

6.1 **Mission date:** 17-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: None.

Feel system: None.

Handling qualities: Felt slightly heavy and response might have been a little slow. Quicker response might have made task easier. Predictable.

Landing: Early power reduction made for adequate touchdowns. Felt desired could have been reached with proper power technique. Needed to hold it off more. Trying to be too smooth. Could be that the aircraft was heavyweight or could be that initial response was a little slow.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Soft	Adequate	6,800	169	10	None	240/10	☐
2	Desired	Soft	Desired	6,500		11	None	240/10	☐
3	Adequate	Soft	Adequate	6,200		11	None	240/10	☐

Cooper-Harper Rating: 3 **Notes on C-H:** Minimal pilot compensation was required. Touchdowns were more on the short side. Aircraft was heavyweight. Even with the two adequate landings felt that this was due more to throttle technique.

Workload Rating: 3 **PIO Rating:** 1

Recommendations: None

7.1 **Mission date:** 17-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: First landing short of Adequate due to a/c weight and winds.

Feel system: Good pitch sensitivity, nice feel and displacement.

Handling qualities: Excellent pitch precision. No tendency to overshoot or bobble. Good resistance to upset due to turbulence. Aggressiveness not a factor, harmony excellent. No conscious compensation required.

Landing: Very good control in the flare. Could put the aircraft right in the Desired box with consistency.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Neither	Medium	Neither	6,700	162	12	None	220/10	☐
2	Desired	Soft	Desired	6,500	167	11	Light	230/11	☐
3	Desired	Soft	Desired	6,300	166	11	None	210/12	☐

Cooper-Harper Rating: 1 **Notes on C-H:** Excellent response all the way around. Great jet.

Workload Rating: 1 **PIO Rating:** 1

Recommendations: Change the F-16 FLCS to this configuration.

8.5 **Mission date:** 18-Sep-95 **Eval pilot:** (#2) Flt. Lt. Justin Paines

Setup: Excellent setups

Feel system: About right to slightly heavy.

Handling qualities: Solid - stable. No undesirable motions, predictable, linear. Response slightly slow for sustained/maneuver. Slight mushiness/lagginess - though initial nose movement response good. Moderate lead / anticipation to compensate for sluggishness. No PIO or bobble. AOA excursion on offset correction due to mushiness of response. Aggressiveness does not effect HQ. Good consistency.

Landing: None.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	3,200	160	10	None	360/3	☐
2	Desired	Soft	Desired	2,900	157	11	None	060/3	☐
3	Desired	Medium	Adequate	2,700	151	10	None	060/3	☐

Cooper-Harper Rating: 4 **Notes on C-H:** Moderate compensation for desired.

Workload Rating: 5 **PIO Rating:** 1

Recommendations: None

10.1 **Mission date:** 19-Sep-95 **Eval pilot:** (#3) Capt. Mark Schaible

Setup: None.

Feel system: Sluggish response of aircraft seemed to aggravate the high stick forces. Good control harmony.

Handling qualities: Aircraft was slightly sluggish. I like the aircraft to respond more quickly to my inputs. The more aggressive I got the more the aircraft seemed to be sluggish. Overall a good handling aircraft.

Landing: First two landings were pilot error due to early power reductions and insufficient flare.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Go-Around	N/A	Neither	4,200			None	350/3	☒ intentional go aroun
2	Adequate	Soft	Adequate	3,900	156	11	None	350/3	☐
3	Go-Around	N/A	Neither	3,700			None	020/4	☒ aircraft on runway
4	Neither	Soft	Neither	3,400	156	11	None	020/4	☐
5	Desired	Soft	Desired	3,100	165	10	None	020/3	☐

Cooper-Harper Rating: 2 **Notes on C-H:** Increased workload drove the CH rating.

Workload Rating: 2 **PIO Rating:** 1

Recommendations: None

Configuration ID

H

Priority: 1 **Actual SP Frequency:** 2.29 **Actual SP Damping Ratio:** 0.97

Actual BW frequency: 2.3 **Tau P:** 0.07

Predicted FQ Levels: **CAP:** 1 **BW:** 1 **BW with DB:** 1

3.3 **Mission date:** 15-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: None.

Feel system: Forces average, maybe a tad on the heavy side, good displacement.

Handling qualities: Harmony good. Pitch response felt a little slow but good command authority. Felt the way the F-16 should feel! Overall, pretty good configuration.

Landing: Pitch sensivity okay in flare. Good pitch power with no tendency toward PIO. Able to get consistent landing attitude and airspeed/AOA control.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Medium	Adequate	4,600	160	11	Light	160/7	☐
2	Desired	Soft	Desired	4,350	156	11	None	100/5	☐
3	Desired	Soft	Desired	4,100	151	12	Light	Calm	☐

Cooper-Harper Rating: 2 **Notes on C-H:** Minor deficiency with pitch command rate.

Workload Rating: 3 **PIO Rating:** 1

Recommendations: None

5.1 **Mission date:** 16-Sep-95 **Eval pilot:** (#3) Capt. Mark Schaible

Setup: None.

Feel system: Excellent, control harmony was excellent

Handling qualities: Extremely easy to put nose where you want it. Power did not affect HQ. Very good feeling A/C. Very predictable. No undesireable characteristics noted

Landing: Second landing was a medium landing due to a high flare

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	6,900	167	9	Light	230/12G2	☐
2	Adequate	Medium	Adequate	6,500	165	11	Light	230/17G2	☐
3	Desired	Soft	Desired	6,200	167	10	Light	230/15G2	☐

Cooper-Harper Rating: 1 **Notes on C-H:**

Workload Rating: 1 **PIO Rating:** 1

Recommendations: None

6.5 **Mission date:** 17-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: None.

Feel system: None.

Handling qualities: Handles relatively well. Quick response (then possibly slowing slightly in steady state). Predictable, maybe a little too quick.

Landing: Slight smoothing, averaging the inputs.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	3,300	162	11	None	220/11	☐
2	Desired	Soft	Desired	3,000	158	11	None	250/13	☐
3	Desired	Soft	Desired	2,800	157	11	None	240/9	☐

Cooper-Harper Rating: 3 **Notes on C-H:** Smoothing inputs considered minimal pilot compensation. The quick response was mildly unpleasant.

Workload Rating: 3 **PIO Rating:** 1

Recommendations: None

Configuration ID

I

Priority: 1 | **Actual SP Frequency:** 3.28 | **Actual SP Damping Ratio:** 0.83

Actual BW frequency: 3 | **Tau P:** 0.07

Predicted FQ Levels: CAP: 1 BW: 1 BW with DB: 2

3.1 **Mission date:** 15-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: Consistently came up final below 3300' AGL (approx. 2800'), caused setup to be a bit tougher with less time on the GS to get AOA/airspeed control down prior to maneuvering. Turned inside east lakeshore for approx. 5 min. patterns.

Feel system: Light stick forces, displacement fine. Good feel system.

Handling qualities: A/C has nice feel. Pitch axis is quick, controllable, and light. Response is very good. Deficiency is slight tendency to high AOA in roundout and flare.

Landing: Tendency to go high on AOA. Very similar to a conventional F-16 in the flare with slightly better pitch pointing and control.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Soft	Adequate	6,500	160	13	None	210/4	☐
2	Adequate	Medium	Adequate	6,100	160	12	None	210/4	☐
3	Desired	Soft	Desired	5,950	150	13	None	210/4	☐

Cooper-Harper Rating: 4 **Notes on C-H:** Minor but annoying deficiencies due to AOA tending to go high.

Workload Rating: 3 **PIO Rating:** 1

Recommendations: None

7.5 **Mission date:** 17-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: Winds down the runway 8 to 11 knots.

Feel system: Forces a bit high in pitch during offset but deadbeat. Stick dynamics aren't too good, a bit too tight

Handling qualities: Good AOA command but initial pitch response is too quick. Pitch response has a bobble that's annoying but doesn't compromise task performance. Overall, a very average configuration that didn't generate a lot of comments.

Landing: Landing in Desired box was pretty easy. No remarkably good or bad characteristics in landing. Pitch sensitivity not a factor in landing.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	3,400	155	11	Light	240/12	☐
2	Desired	Soft	Desired	3,100	153	11	Light	200/11	☐
3	Desired	Soft	Desired	2,900	156	11	Light	200/11	☐

Cooper-Harper Rating: 5 **Notes on C-H:** Deficiency with pitch bobble is pretty major and very distracting, stick forces too high.

Workload Rating: 6 **PIO Rating:** 2

Recommendations: None

8.1 **Mission date:** 18-Sep-95 **Eval pilot:** (#2) Flt. Lt. Justin Paines

Setup: Excellent setups.

Feel system: Stick forces a little high.

Handling qualities: Solid, reasonably high control forces. No undesirable motions; predictable. Initial response about right (pitch response) - slow response for maneuver/sustained response. Not pitch sensitive. Minimal compensation (lead). Good consistency.

Landing: None.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Go-Around	N/A	Neither	6,800			None	090/5	☒ Flap rate limit
2	Desired	Soft	Desired	6,500	170	11	None	Calm	☐
3	Desired	Soft	Desired	6,300	170	10	None	360/4	☐
4	Desired	Soft	Desired	6,000	168	10	None	360/4	☐

Cooper-Harper Rating: 4 **Notes on C-H:** Moderate compensation required for desired.

Workload Rating: 5 **PIO Rating:** 1

Recommendations: None

9.1 **Mission date:** 18-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: None.

Feel system: None.

Handling qualities: Heavy. Couldn't get the motion desired, so had to pull more. Initial response felt too slow. It was predictable.

Landing: Felt heavy. Sluggish in the flare. The third landing produced a pitch bobble during the round-out that was noticeable but easily compensated. Tendency to float trying to let the aircraft down but couldn't get the nose down with smooth, small motion. Workload was moderate.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	6,800	162	12	Light	010/9	☐
2	Adequate	Medium	Adequate	5,900	172	9	None	090/8	☐
3	Adequate	Soft	Adequate	5,600	167	10	None	090/8	☐

Cooper-Harper Rating: 5 **Notes on C-H:** It was moderately objectionable and pilot compensation was considerable but not too high.

Workload Rating: 4 **PIO Rating:** 2

Recommendations: None

Configuration ID

J

Priority: 1 **Actual SP Frequency:** 1.44 **Actual SP Damping Ratio:** 0.21

Actual BW frequency: 1.7 **Tau P:** 0.08

Predicted FQ Levels: **CAP:** 1 **BW:** 2 **BW with DB:** 3

3.2 **Mission date:** 15-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: None

Feel system: Heavy stick, felt sluggish. Sloppy and slow pitch response in flare. Displacement a bit large for pitch response.

Handling qualities: Pitch response pretty deadbeat. Poor consistency due to loss of pitch power in flare.

Landing: Ran out of pitch power in the flare. Stick pretty far aft and no nose motion. Nothing left to pull with in flare, nose dropping, caused medium firmness.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Neither	Medium	Neither	5,700	157	13	None	210/4	☒ Safety pilot trip
2	Adequate	Medium	Adequate	5,300	161	11	Light	210/4	☐
3	Desired	Soft	Desired	4,850	155	11	Light	160/7	☐

Cooper-Harper Rating: 6 **Notes on C-H:** Very objectionable deficiencies.

Workload Rating: 5 **PIO Rating:** 1

Recommendations: Check command gains on this configuration.

6.3 **Mission date:** 17-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: None.

Feel system: Felt a little stiff.

Handling qualities: Response seemed a little slow.

Landing: Some landings showed a slow open loop technique, another showed a quick jabbing motion. Higher AOA touchdowns possibly because of slow response of stick, so touched down earlier than desired, (Firm and Fast)

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Medium	Adequate	4,800	167	10	None	230/13	☐
2	Desired	Medium	Adequate	4,700	172	8	None	230/13	☐
3	Desired	Soft	Desired	4,300		11	None	230/11	☐

Cooper-Harper Rating: 5 **Notes on C-H:** Slightly due to workload, mostly because adequate performance was due to firmness of the touchdowns.

Workload Rating: 6 **PIO Rating:** 1

Recommendations: None

8.2 **Mission date:** 18-Sep-95 **Eval pilot:** (#2) Flt. Lt. Justin Paines

Setup: Excellent setups.

Feel system: A little too high forces.

Handling qualities: Sluggish response. Mushiness/slow response. Compensation: anticipation/lead required. Slow response of a/c results in overshoots (overcontrol) / slow oscillations in pitch (not divergent) - does not seem totally predictable. Linear response. Aggressivenes does not effect HQ. Mushiness gives alpha excursions during offset correction.

Landing: None.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Soft	Adequate	5,900	165	10	None	360/5	☐
2	Desired	Medium	Adequate	5,600	171	10	None	020/5	☐
3	Desired	Soft	Desired	5,200	165	10	None	070/6	☐

Cooper-Harper Rating: 4.5 **Notes on C-H:** Considerable compensation for desired performance.

Workload Rating: 6 **PIO Rating:** 3

Recommendations: None

9.4 **Mission date:** 18-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: Felt stiff, or heavy.

Feel system: None.

Handling qualities: Stiff or heavy. Not sensitive enough. Slow initially.

Landing: Compensating because it felt heavy. Motion in the flare was stair stepping. Move stick aft (pause)...check nose movement (not enough)....move stick aft (pause)...etc. Didn't get the desired motion of the nose I'd like to see.. Touchdowns were medium because I could not get the nose authority I wanted. Smoothing techniques were to back out of the loop.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	3,200	167	9	None	270/4	☐
2	Desired	Medium	Adequate	3,000	155	11	None	180/4	☐
3	Desired	Medium	Adequate	2,800	162	11	Light	Calm	☐

Cooper-Harper Rating: 5 **Notes on C-H:** Adequate. Deficiencies warranted some improvement and were moderately objectionable. Considerable pilot compensation required.

Workload Rating: 4 **PIO Rating:** 1

Recommendations: None

Configuration ID

K

Priority: 1

Actual SP Frequency:

Actual SP Damping Ratio:

Actual BW frequency: 1.9

Tau P: 0.08

Predicted FQ Levels: **CAP:** 1 **BW:** 2 **BW with DB:** 2

4.2

Mission date: 16-Sep-95 **Eval pilot:** (#2) Flt. Lt. Justin Paines

Setup: Excellent on first 2 approaches. Half dot high at maneuver on last 2 approaches.

Feel system: Forces a little high.

Handling qualities: A lot of trimming required (speed stability?): fairly solid. Stable. No undesirable motions. Predictable, linear. Response a little-slow - larger inputs required for desired output. Higher forces required in flare. Aggressiveness does not effect HQ. Slow to give me what I want. VSS trip on one approach during initial offset maneuver due rate limit.

Landing: Desired and adequate criteria each met on 2 approaches.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Go-Around	N/A	Neither	5,900		0	None	210/6	☒ Flaperon rate limit
2	Desired	Soft	Desired	5,800	160	11	None	230/8	☐
3	Desired	Soft	Desired	5,400	160	10	None	240/9	☐
4	Adequate	Soft	Adequate	5,000	156	12	None	240/8	☐
5	Adequate	Soft	Adequate	4,800	157	11	None	220/7	☐

Cooper-Harper Rating: 4 **Notes on C-H:** Didn't always meet desired - moderate compensation for desired.

Workload Rating: 4 **PIO Rating:** 1

Recommendations: None

5.2

Mission date: 16-Sep-95 **Eval pilot:** (#3) Capt. Mark Schaible

Setup: None.

Feel system: Stick forces were too high longitudinally compared with lateral forces. Small movements of 1" or less produced no movement of the nose. High longitudinal forces impacted control harmony. Stick forces increased drastically past 1-2" of displacement.

Handling qualities: Slight longitudinal oscillation (can't call it a PIO) during the maneuver to landing affected overall HQ because there was no way to predict how the oscilation would affect the aircraft, therefore, it negatively affected both the control harmony and the predictability. Usually required a push input followed by a pull input. Lack of predictability of my input did not allow me to compensate or smooth out either of these inputs. Sluggish response affected my ability to compensate for winds/turbulence. When I wanted to be aggressive, the sluggish response damped almost all of my inputs effectively taking me out of the loop.

Landing: High stick forces/sluggish reponse increased work load during flare and landing.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Soft	Adequate	6,000	162	11	Light	230/17G2	☐
2	Desired	Soft	Desired	5,700	164	11	Light	220/17G2	☐
3	Desired	Soft	Desired	5,300	170	10	Light	260/16G2	☐

Cooper-Harper Rating: 3 **Notes on C-H:** Higher workload and decreased flying qualities.

Workload Rating: 4 **PIO Rating:** 1

Recommendations: None

6.6 **Mission date:** 17-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: None.

Feel system: None.

Handling qualities: Response seemed to ramp up very slightly. Slow initially then quicker steady state. Slightly pitch sensitive. Handled OK. There was still something I didin't like, but couldn't put my finger on it.

Landing: Slight smoothing technique. Workload low to medium.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1*	Desired	Soft	Desired	2,500	157	10	None	240/10	☐
2	Desired	Soft	Desired	2,200		11	None	250/13	☐
3	Desired	Medium	Adequate	1,900		11	None	250/13	☐

Cooper-Harper Rating: 3 **Notes on C-H:** Workload low to medium, mildly unpleasant but can't put my finger on it.

Workload Rating: 4 **PIO Rating:** 1

Recommendations: None

7.3 **Mission date:** 17-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: None.

Feel system: Stick is deadbeat. Displacement high for small nose motions.

Handling qualities: Pitch response too slow and has a small lag. Compensating by making larger, faster inputs (leading) to get desired pitch response. Tended to overshoot desired pitch attitude due to size of inputs. Fairly deadbeat in pitch. Workload fairly high due to requirement to lead inputs and lack of pitch power in flare. PIO rating of 3 due to undesirable pitch motions resulting from large, fast inputs.

Landing: Ran out of pitch authority in the flare. Second approach got Adequate due to wide lateral displacement on runway. Pitch sensitivity too low in the flare. Aggressiveness of corrections in flare not a factor to performance.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	5,000	161	11	None	240/12	☐
2	Adequate	Firm	Neither	4,800	157	11	Light	250/14	☐
3	Desired	Soft	Desired	4,600	159	11	Light	220/12	☐

Cooper-Harper Rating: 5 **Notes on C-H:** Considerable pilot compensation required by leading inputs.

Workload Rating: 7 **PIO Rating:** 3

Recommendations: None

9.2 **Mission date:** 18-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: None.

Feel system: None.

Handling qualities: Felt like I could put it where I wanted to. Good initial response. Predictable with no undesirable motions.

Landing: Low gain used because high gain not required. Late power reduction produced one long adequate landing. Power reduction not a compenastion for poor handling qualities, compensation for heavyweight when the aircraft was more medium weight. Slight tendency to float, almost felt like the power wasn't in idle. Felt like I had to let it down and possibly a little slow to let it down when back pressure released.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	5,300	166	11	None	040/9	☐
2	Adequate	Soft	Adequate	0	165	11	None	040/9	☐
3	Desired	Soft	Desired	0	166	11	None	040/9	☐

Cooper-Harper Rating: 2 **Notes on C-H:** Pilot compensation was not a factor. Deficienices were negligible.

Workload Rating: 2 **PIO Rating:** 1

Recommendations: None

9.5 **Mission date:** 18-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: None.

Feel system: None.

Handling qualities: Intial response seemed slow but then would rapidly increase to a qiuck steady state. It felt unpredictable, as though it was not linear. It felt sensitive but not touchy.

Landing: In the flare the stick techniques showed the stick slowly moving aft overall, but the stick would move aft smoothly... stop...a quick jab forward...smoothly aft...stop, a quick jab forward...etc. Flare got quicker than anticipated response (slow then quick .. getting too much pitch rate/attitude).

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Medium	Adequate	2,600	149	12	None	040/4	☐
2	Desired	Medium	Adequate	2,300	156	11	None	020/7	☐
3	Desired	Medium	Adequate	2,000	154	11	None	Calm	☐

Cooper-Harper Rating: 6 **Notes on C-H:** Deficiencies warrant improvement. Very objectionable. Extensive pilot compensation required...very close to giving it a Cooper-Harper of 7.

Workload Rating: 5 **PIO Rating:** 1

Recommendations: None

Configuration ID	**Priority:** 2	**Actual SP Frequency:** 1.2	**Actual SP Damping Ratio:** 0.44
P		**Actual BW frequency:** 1.4	**Tau P:** 0.08
		Predicted FQ Levels: **CAP:** 1	**BW:** 2 **BW with DB:** 2

3.5 **Mission date:** 15-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: Able to get a/c trimmed-up on the glidepath, but entering the loop sends the nose shooting off in pitch.

Feel system: Stick dynamics are fine, but the airplane is lousy.

Handling qualities: Extreme tendency for nose to pitch off. Very sloppy in the pitch axis with a large amplitude, low frequency oscillation. Any pitch input causes nose to wobble off. Backed out of loop to maintain pitch attitude but it is controllable. Had to smooth inputs and work hard to maintain desired nose track. Aggressiveness in lateral correction excited pitch problem.

Landing: Turbulence in the overrun causes nose to wander off. Tendency toward PIO in the flare when in tight control in the loop. Very wary of getting into the loop in the flare. VSS trip on landing #3 due to PIO in flare -- pitch rate prediction (VIM) tripped off. Definite PIO. Compensated by setting up landing attitude and basically let the aircraft fly itself down to the runway hands-off.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Medium	Adequate	3,100	162	11	Light	230/10	☐
2	Adequate	Medium	Adequate	2,900	152	13	Light	260/12	☐
3	Adequate	Medium	Adequate	2,650	152	11	Light	230/12	☒ Pitch rate limit
4	Adequate	Firm	Neither	2,300	150	13	None	240/10	☐

Cooper-Harper Rating: 8 **Notes on C-H:** Very high compensation required for control in flare.

Workload Rating: 9 **PIO Rating:** 5

Recommendations: None

4.5 **Mission date:** 16-Sep-95 **Eval pilot:** (#2) Flt. Lt. Justin Paines

Setup: Good setups - but 1 dot high on 2nd approach.

Feel system: Forces/displacements too light. Stick too sensitive. Difficult to determine the contribution this makes to the PIO tendencies/poor FQs.

Handling qualities: Very pitch sensitive (not twitchy - slower rate than twitchiness) but tendency to overshoot desired response to control input, strong tendency for PIO. Controls very sensitive. Aggressiveness has very strong effect - must be very smooth. However, difficult to assess this due trip (see rec below). Low gain control with compensation fine - no PIO. Compensation required: anticipation and smoothing; backing out of loop required; being very gentle on controls. This form of compensation is natural to the pilot, so that, though compensation was extensive, workload was high but not very high. Without compensation, control is in question.

Landing: None

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Medium	Adequate	2,800	157	10	None	210/8	☐
2	Go-Around	N/A	Neither	2,600			None	220/8	☒ Unknown
3	Desired	Soft	Desired	2,300	152	11	None	220/8	☐
4	Desired	Soft	Desired	2,100	152	11	None	200/8	☐

Cooper-Harper Rating: 8 **Notes on C-H:** Controllability in question.

Workload Rating: 6 **PIO Rating:** 4

Recommendations: Repeat test point with high gain pilot inputs with cause of above trip dissabled to investigate if PIO becomes divergent at high pilot gain.

5.3 **Mission date:** 16-Sep-95 **Eval pilot:** (#3) Capt. Mark Schaible

Setup: None.

Feel system: Large longitudinal forces.

Handling qualities: Strong tendency to PIO on final. The more aggressive you get, the more out of phase you became with the PIO. Made the aircraft unpredictable because you couldn't put it where you wanted it. Response of aircraft to inputs is also slow, which complicates the PIO. Aircraft required considerable pilot compensation (smoothing) to keep A/C from diverging. Winds and turbulence also aggravated the PIO. Ground effect tended to dampen out the PIO.

Landing: None.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Soft	Adequate	4,900	167	11	Light	260/16G2	☐
2	Desired	Soft	Desired	4,700	165	11	Light	260/16G2	☐
3	Adequate	Soft	Adequate	4,400	165	10	Light	260/16G2	☐

Cooper-Harper Rating: 5 **Notes on C-H:** Deficiencies in flying qualities warrant improvement. Increased pilot workload.

Workload Rating: 5 **PIO Rating:** 4

Recommendations: None

6.2 **Mission date:** 17-Sep-95 **Eval pilot:** (#4) Capt. Nils Larson

Setup: Slow undesirable pitch motions noted on final. When maneuvering during the offset the motion became worse.

Feel system: None.

Handling qualities: Slow pitch bobble noted. Aggressiveness increased the amplitude of the pitch bobble. Side gust also ended up effecting the pitch axis and inceasing the amplitude of the bobble.

Landing: Compensation required a lot of small, quick, jabbing motions. Very high workload.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Desired	Soft	Desired	6,000		11	None	240/8	☐
2	Desired	Medium	Adequate	5,700		11	None	230/12	☐
3	Adequate	Soft	Adequate	5,200		11	None	230/13	☐

Cooper-Harper Rating: 7 **Notes on C-H:** Adeqaute and desired performance were attained however the workload was high and this is a major defficiency which will require improvement.

Workload Rating: 1 **PIO Rating:** 2

Recommendations: None

7.4 **Mission date:** 17-Sep-95 **Eval pilot:** (#1) Capt. Chris McCann

Setup: None.

Feel system: Stick feels stiff, not too sensitive. Displacement okay, but forces too high.

Handling qualities: Turbulence caused large, quick AOA excursions, airplane felt sloppy. Slow, deadbeat pitch response. AOA command is sloppy and imprecise.

Landing: First landing got a VSS trip due to pitch rate monitor. Incipient stages of pitch PIO in the flare, went through 1.5 cycles before tripping off. AOA excursions went from 11 to 13 to 8, then VSS tripped. Ran out of pitch command in flare. Normal, drug-in approach required lots of pitch inputs approaching touchdown. Compensated by coming in steeper, requiring fewer pitch inputs in flare. Set a/c up on glidepath, drove it down to the touchdown point.

Appr	Landing zone	TD Firm	Criteria met	Fuel	A/S	AOA	Turb	Wind	VSS Trip and reason
1	Adequate	Medium	Adequate	4,300	157	13	Light	250/10	☒ Pitch rate limit
2	Desired	Soft	Desired	4,000	157	12	None	250/8	☐
3	Desired	Soft	Desired	3,700	163	11	None	240/10	☐

Cooper-Harper Rating: 6 **Notes on C-H:** Pilot compensation too high.

Workload Rating: 5 **PIO Rating:** 3

Recommendations: None

Have CAP Flying Qualities Level Prediction Correlation

06-Dec-95

						Flying Qualities Predictions					
Config	Test Pt	Pilot	C-H	PIO	HQ Level	CAP	Match	BW	Match	BW w/Drb	Match
A	3.4	1 McCann	7	4	3	2	No	2	No	3	Yes
	4.4	2 Paines	7	4	3	2	No	2	No	3	Yes
	5.5	3 Schaible	6	4	2	2	Yes	2	Yes	3	No
	6.4	4 Larson	8	4	3	2	No	2	No	3	Yes
	8.3	2 Paines	7	4	3	2	No	2	No	3	Yes
C-H: X = 7	σ = 0.71	Xmo = 7	Xmd = 7	PIO: X = 4	σ = 0	Xmo = 4	Xmd = 4	HQ Lvl: X = 2.8	σ = 0.45	Xmo = 3	Xmd = 3
C2	3.6	1 McCann	6	4	2	2	Yes	2	Yes	2	Yes
	5.4	3 Schaible	6	3	2	2	Yes	2	Yes	2	Yes
	10.2	3 Schaible	4	3	2	2	Yes	2	Yes	2	Yes
C-H: X = 5.33	σ = 1.15	Xmo = 6	Xmd = 6	PIO: X = 3.33	σ = 0.58	Xmo = 3	Xmd = 3	HQ Lvl: X = 2	σ = 0	Xmo = 2	Xmd = 2
D	4.3	2 Paines	8	4	3	2	No	2	No	2	No
	7.2	1 McCann	7	4	3	2	No	2	No	2	No
	8.4	2 Paines	7	4	3	2	No	2	No	2	No
	9.3	4 Larson	7	4	3	2	No	2	No	2	No
C-H: X = 7.25	σ = 0.5	Xmo = 7	Xmd = 7	PIO: X = 4	σ = 0	Xmo = 4	Xmd = 4	HQ Lvl: X = 3	σ = 0	Xmo = 3	Xmd = 3
E	4.1	2 Paines	2	2	1	1	Yes	1	Yes	2	No
	5.6	3 Schaible	2	1	1	1	Yes	1	Yes	2	No
	10.3	3 Schaible	1	1	1	1	Yes	1	Yes	2	No
C-H: X = 1.67	σ = 0.58	Xmo = 2	Xmd = 2	PIO: X = 1.33	σ = 0.58	Xmo = 1	Xmd = 1	HQ Lvl: X = 1	σ = 0	Xmo = 1	Xmd = 1
G	6.1	4 Larson	3	1	1	1	Yes	1	Yes	1	Yes
	7.1	1 McCann	1	1	1	1	Yes	1	Yes	1	Yes
	8.5	2 Paines	4	1	2	1	No	1	No	1	No
	10.1	3 Schaible	2	1	1	1	Yes	1	Yes	1	Yes
C-H: X = 2.5	σ = 1.29	Xmo = N/A	Xmd = 2.5	PIO: X = 1	σ = 0	Xmo = 1	Xmd = 1	HQ Lvl: X = 1.25	σ = 0.5	Xmo = 1	Xmd = 1
H	3.3	1 McCann	2	1	1	1	Yes	1	Yes	1	Yes
	5.1	3 Schaible	1	1	1	1	Yes	1	Yes	1	Yes
	6.5	4 Larson	3	1	1	1	Yes	1	Yes	1	Yes
C-H: X = 2	σ = 1	Xmo = N/A	Xmd = 2	PIO: X = 1	σ = 0	Xmo = 1	Xmd = 1	HQ Lvl: X = 1	σ = 0	Xmo = 1	Xmd = 1
I	3.1	1 McCann	4	1	2	1	No	1	No	2	Yes
	7.5	1 McCann	5	2	2	1	No	1	No	2	Yes
	8.1	2 Paines	4	1	2	1	No	1	No	2	Yes
	9.1	4 Larson	5	2	2	1	No	1	No	2	Yes
C-H: X = 4.5	σ = 0.58	Xmo = 4.5	Xmd = 4.5	PIO: X = 1.5	σ = 0.58	Xmo = 1,2	Xmd = 1.5	HQ Lvl: X = 2	σ = 0	Xmo = 2	Xmd = 2
J	3.2	1 McCann	6	1	2	1	No	2	Yes	3	No
	6.3	4 Larson	5	1	2	1	No	2	Yes	3	No
	8.2	2 Paines	4.5	3	2	1	No	2	Yes	3	No
	9.4	4 Larson	5	1	2	1	No	2	Yes	3	No
C-H: X = 5.13	σ = 0.63	Xmo = 5	Xmd = 5	PIO: X = 1.5	σ = 1	Xmo = 1	Xmd = 1	HQ Lvl: X = 2	σ = 0	Xmo = 2	Xmd = 2
K	4.2	2 Paines	4	1	2	1	No	2	Yes	2	Yes
	5.2	3 Schaible	3	1	1	1	Yes	2	No	2	No
	6.6	4 Larson	3	1	1	1	Yes	2	No	2	No
	7.3	1 McCann	5	3	2	1	No	2	Yes	2	Yes
	9.2	4 Larson	2	1	1	1	Yes	2	No	2	No
	9.5	4 Larson	6	1	2	1	No	2	Yes	2	Yes
C-H: X = 3.83	σ = 1.47	Xmo = 3	Xmd = 3.5	PIO: X = 1.33	σ = 0.82	Xmo = 1	Xmd = 1	HQ Lvl: X = 1.5	σ = 0.55	Xmo = 1,2	Xmd = 1.5
P	3.5	1 McCann	8	5	3	1	No	2	No	2	No
	4.5	2 Paines	8	4	3	1	No	2	No	2	No
	5.3	3 Schaible	5	4	2	1	No	2	Yes	2	Yes
	6.2	4 Larson	7	2	3	1	No	2	No	2	No
	7.4	1 McCann	6	3	2	1	No	2	Yes	2	Yes
C-H: X = 6.8	σ = 1.30	Xmo = 8	Xmd = 7	PIO: X = 3.6	σ = 1.14	Xmo = 4	Xmd = 4	HQ Lvl: X = 2.6	σ = 0.55	Xmo = 3	Xmd = 3

CAP Prediction Correlation

Config ID	Prediction Matches	Accuracy
A	1	20%
C2	3	100%
D	0	0%
E	3	100%
G	3	75%
H	3	100%
I	0	0%
J	0	0%
K	3	50%
P	0	0%
Total Matches =	16	39% (16/41)

BW with Dropback Prediction Correlation

Config ID	Prediction Matches	Accuracy
A	4	80%
C2	3	100%
D	0	0%
E	0	0%
G	3	75%
H	3	100%
I	4	100%
J	0	0%
K	3	50%
P	2	40%
Total Matches =	22	54% (22/41)

Bandwidth Prediction Correlation

Config ID	Prediction Matches	Accuracy
A	1	20%
C2	3	100%
D	0	0%
E	3	100%
G	3	75%
H	3	100%
I	0	0%
J	4	100%
K	3	50%
P	2	40%
Total Matches =	22	54% (22/41)

APPENDIX C

PILOT COMMENT CARD, COOPER-HARPER RATING SCALE, AND PILOT-INDUCED OSCILLATION RATING SCALE

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PILOT COMMENT CARD

TEST POINT #:	LANDING #:	TURBULENCE:
EVAL PILOT:		WINDS:

Card #

TOUCHDOWN FIRMNESS (EVAL): SOFT MEDIUM FIRM

TOUCHDOWN FIRMNESS (SAFETY): SOFT MEDIUM FIRM

LANDING ZONE POSITION: DESIRED ADEQUATE NEITHER

COOPER-HARPER RATING ____

INPUTS REQUIRED:

1. Undesirable Motions? (Axis? Amplitude?)
2. Predictable? (Linearity?)
3. Initial Response? (Too Quick / Too Slow)
4. Pitch Sensitivity? (Higher in flare? Touchy?)
5. Aggressiveness Affects Handling Qualities?
6. Compensation Techniques? (Smoothing, back out of loop?)
7. PIO Rating: ______ (use PIO scale)
8. Problems with Approach, Line Up, Flare, Touchdown, Tendency to Float?

FEEL SYSTEM:

1. Forces - Too High/ Too Low?
2. Control Displacement - Too Much / Too Little?
3. Harmony? (Did it affect the task?)
4. Nonlinearities?

GENERAL:

1. Did Turbulence / Wind effect the task? How?
2. Consistency of performance?
3. Other comments?

LIGHT HEAVY

Workload |________________________|

COOPER-HARPER RATING _______

Figure C1 Pilot Comment Card

HANDLING QUALITIES RATING SCALE

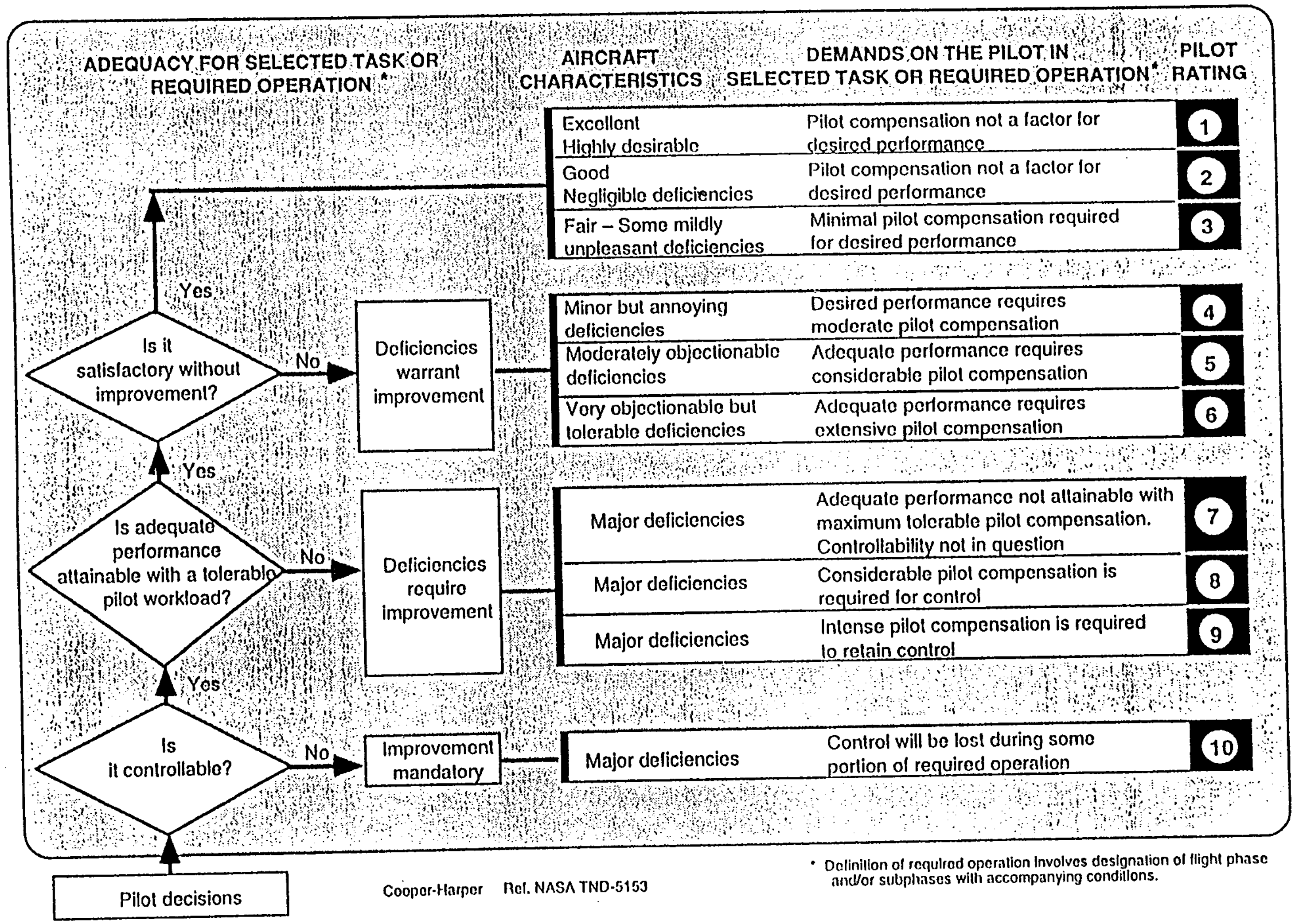

Figure C2 Cooper-Harper Rating Scale

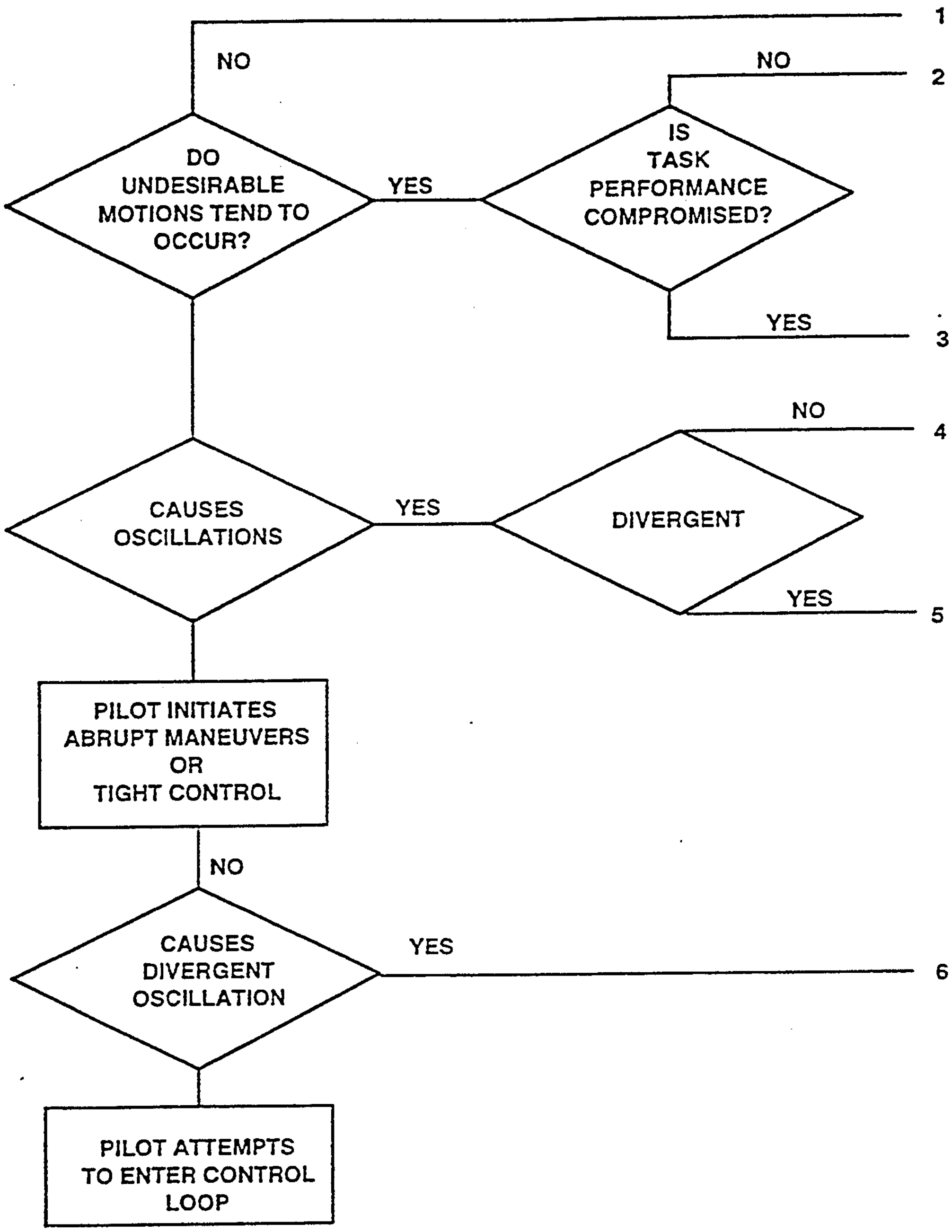

Figure C3 Pilot-Induced Oscillation Rating Scale

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APPENDIX D

CAP, BANDWIDTH, AND DROPBACK DEFINITIONS AND MAPPINGS

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CAP, BANDWIDTH, AND DROPBACK DEFINITIONS AND MAPPINGS

CONTROL ANTICIPATION PARAMETER

The control anticipation parameter (CAP) was defined as the ratio of an aircraft's initial pitching acceleration, $\ddot{\Theta}_0$, to its steady-state normal acceleration, $\Delta n_{z_{ss}}$, where all accelerations were measured about the instantaneous center of gravity. For aircraft with classical longitudinal second order responses, this can mathematically be represented as:

$$CAP \equiv \frac{\ddot{\Theta}_0}{\Delta n_{Z_{SS}}} = \frac{W\bar{c}C_{m_{C_L}} + \frac{1}{4}S\bar{c}^2 \rho g C_{m_{\dot{\Theta}}}}{-I_Y\left[1 + \dfrac{C_{m_{C_L}}}{l_t/\bar{c}}\right]}$$

$$\approx \frac{\omega_{sp}^2}{n/\alpha} \approx \frac{\omega_{sp}^2}{\dfrac{V}{g}\dfrac{1}{T_{\Theta_2}}} \quad \left(\frac{rad/\sec}{g}\right), \tag{D1}$$

where:

- W ≡ aircraft's total weight
- $\overline{C}$ ≡ mean aerodynamic chord
- $C_{m_{C_L}}$ ≡ change in pitching moment coefficient due to a change in lift coefficient
- S ≡ wing reference area
- ρ ≡ air density
- g ≡ acceleration due to gravity
- $C_{m_{\dot{\Theta}}}$ ≡ change in pitching moment due to a change in pitch attitude rate
- I_y ≡ moment of inertia about the aircraft's y-body axis
- l_t ≡ tail arm, 0.25 $\overline{C}$ of tail to 0.25 $\overline{C}$ of wing
- ω_{sp} ≡ undamped short period natural frequency
- n/α ≡ the steady-state normal acceleration change per unit change in angle of attack for an incremental pitch control deflection at constant airspeed and Mach number
- V ≡ true airspeed
- $1/T_{\Theta_2}$ ≡ high frequency pitch attitude zero.

The approximations in Equation D1 can be derived using the longitudinal short period approximation and the above definition.

The CAP criterion required aircraft with higher order longitudinal modes of motion, i.e., aircraft which had more modes than the classical short period and phugoid modes, be reduced to a lower order equivalent system (LOES) as outlined in MIL-STD-1797A, page 179. The LOES match resulted in a classical pitch attitude transfer function of the form:

$$\frac{\Theta(s)}{\delta(s)} = \frac{M_\delta\left(s + 1/T_{\Theta_1}\right)\left(s + 1/T_{\Theta_2}\right)e^{-\tau_\Theta s}}{\left(s^2 + 2\zeta_{ph}\omega_{ph}s + \omega_{ph}^2\right)\left(s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2\right)},$$

or using the short period approximation,

$$\frac{\Theta(s)}{\delta(s)} \approx \frac{K_\Theta\left(s + 1/T_{\Theta_2}\right)e^{-\tau_\Theta s}}{s\left(s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2\right)} \tag{D2}$$

where:

- δ ≡ deflection of pitch manipulator (commonly the elevator or canard)
- K_Θ ≡ gain associated with the short period transfer function

M_δ ≡ pitching moment due to deflection of the pitch manipulator

$1/T_{\Theta_1}$ ≡ low frequency zero

$e^{-\tau_\Theta s}$ ≡ higher order time delay

ω_{ph} ≡ undamped phugoid natural frequency

ζ_{ph} ≡ phugoid damping ratio

ζ_{sp} ≡ short period damping ratio.

The magnitude of CAP gave the pilot an indication of the final steady-state normal acceleration from the aircraft's initial pitching acceleration. This was essential because of the time lag between the pilot's input and the final steady-state normal acceleration. For example, aircraft with the desired flightpath and tend to rate the aircraft as being fast, abrupt, and sensitive.

On the other hand, a low CAP meant the initial pitching acceleration was low compared to the final steady-state normal load factor. Longitudinal control inputs changing the pitch attitude caused pilots to sense low initial pitching accelerations. Thus, pilots would increase control inputs to achieve the desired pitching acceleration. However, due to the lag between the initial pitching acceleration and the steady-state normal acceleration, a large steady-state normal acceleration would result and the desired flightpath would be over-shot. Pilot comments would typically classify the aircraft as being sluggish. Therefore, the magnitude of CAP was used as an indirect measure of pilot opinion as the aircraft was flown on the glideslope (Reference 1, page 6).

The CAP boundaries for the landing phases of flight, as presented in MIL-STD-1797A, are shown in Figure D1. Levels 1, 2, and 3 correspond to the Cooper-Harper Pilot Rating Scale. The CAP in the figure was defined from Equation D1 using the LOES match. In addition to Figure D1, MIL-STD-1797A restricted ω_{sp}, n/α, and τ_Θ in the landing task as specified in Tables D1 and D2.

In summary, CAP was be used to predict pilot opinion of an aircraft's longitudinal mode of motion. To make precise flightpath adjustments, a pilot must be able to anticipate the ultimate response from the instantaneous motion of the aircraft. Longitudinally, the instantaneous motion is sensed through pitching accelerations. Thus, "the amount of instantaneous angular pitching acceleration per unit of steady state normal acceleration is.an index of the strength of the anticipation signal received by the pilot." (Reference 1, page 5)

BANDWIDTH CRITERION

> In the field of aircraft handling qualities, "bandwidth," defined by the highest open-loop cross over frequency attainable with good closed-loop dynamics, is typically used to measure the speed of response a pilot can expect when tracking with rapid control inputs. Bandwidth indicates how tightly the pilot can close the loop without threatening the stability of the pilot/vehicle system; it is a measure of tracking precision and disturbance rejection. (Reference 2, page 45)

Classical control theory defines the bandwidth frequency, ω_{BW}, as that frequency where the closed loop magnitude is 3 dB down from the low frequency value—typically 0 dB when the closed loop system is low pass. When the system is first order, ω_{BW} is the open loop's crossover frequency. Thus, ω_{BW} can be a good measure of the closed-loop system's time response (Reference 2, page 45).

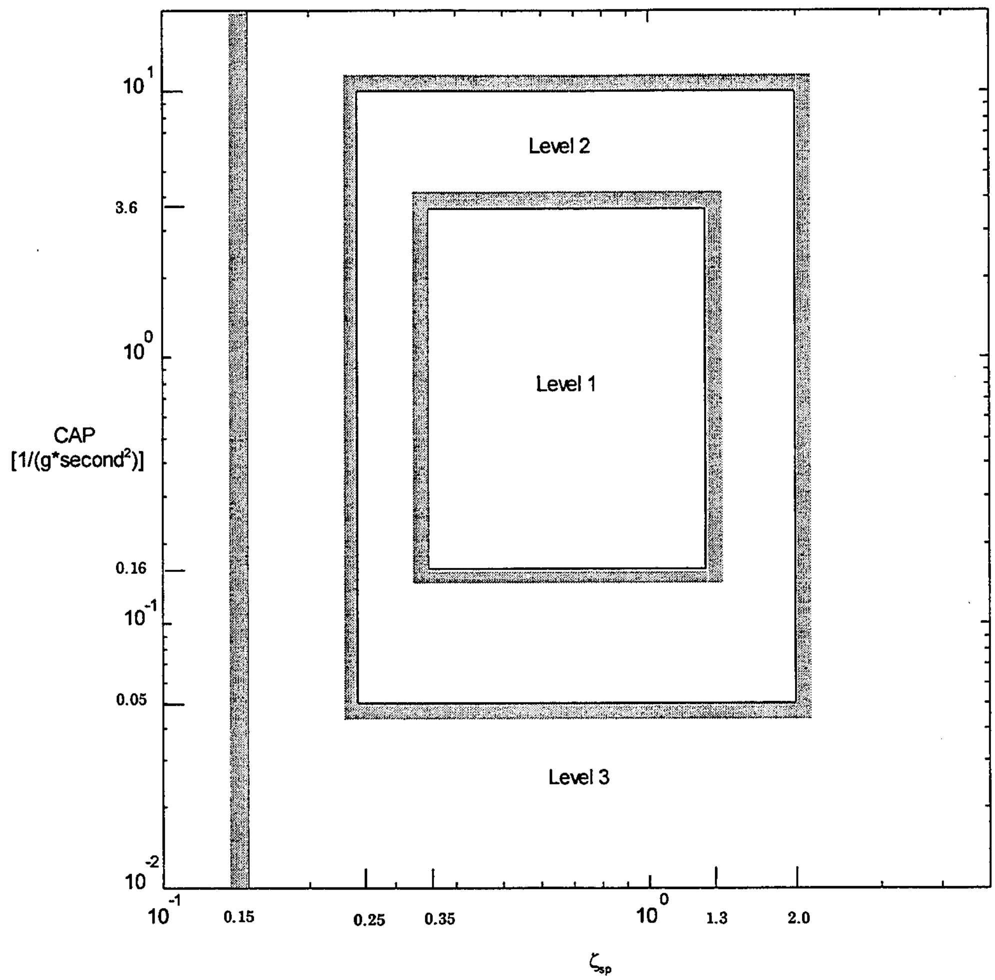


Figure D1 Landing Phase CAP Criterion

Table D1
CAP REQUIREMENTS ON ω_{sp} AND n/α (LANDING TASK)

Class	Level 1 $\omega_{sp}\rvert_{min}$ (rad/sec)	Level 1 $n/\alpha\rvert_{min}$ (g/rad)	Level 2 $\omega_{sp}\rvert_{min}$ (rad/sec)	Level 2 $n/\alpha\rvert_{min}$ (g/rad)
IV	0.87	2.7	0.6	1.8

Note: For Level 3, the time to double amplitude, based on the unstable root, shall be no less than 6 seconds. In the presence of any other Level 3 flying qualities, ζ_{sp} shall be at least 0.05 unless flight safety is otherwise demonstrated to the satisfaction of the procuring agency.

Table D2
CAP REQUIREMENT
ON TIME DELAY (LANDING TASK)

Level	Allowable Delay (sec)
1	0.10
2	0.20
3	0.25

The bandwidth criterion, as defined in MIL-STD-1797A, was specifically developed for highly augmented aircraft which do not have traditional modes of motion. This criterion was derived from flight test results of the YF-16 Fighter Control Configured Vehicle. The YF-16 evaluated the effectiveness of independent control of ventral canards for side force generation and existing wing flaps for direct lift generation. Benefits of the bandwidth criterion were that it did not require a LOES match, nor did it rely on a pilot model.

The longitudinal bandwidth handling quality metric, ω_{BW}, was defined as the highest frequency where the open-loop system had at least a 45-degree phase margin and a 6 dB gain margin. This essentially judged the pilot's ability to double the gain or add a time delay without causing longitudinal instability. Note the gain and phase margins were not defined in the classical way. The gain margin was not defined from encirclements of the -1 point on the system's Nyquist plot (i.e., the gain required to cause instability at a phase angle of -180 degrees) because of the difficulty in defining the nominal gain. Therefore, a gain of 6 dB from the -180-degree frequency, ω_{180}, was chosen to indicate a doubling of the pilot's gain. The phase margin definition was derived from

> "...the relationship between closed-loop damping and open-loop phase margin for an ideal open-loop plant ($G = Ke^{-\tau s}/s$ where τ was the pilot's time delay).as shown in Figure D2. A study of simulation data using pilot/vehicle analysis techniques showed a closed-loop damping ratio of 0.35 set the approximate boundary between undesirable and desirable flying qualities" (Reference 2, page 45).

As illustrated in Figure D2, this corresponded to an approximate phase margin of 45 degrees. Again because of the difficulty in defining the nominal gain, the phase margin was defined as the frequency where the open-loop Bode plot had a phase angle of -135 degrees (i.e., -180 degrees + 45 degrees). Using Figure D2 for higher order systems was justified since this criterion assumed the pilot would supply the needed leads or lags to make the system's response look like the response of K/s (Reference 2, page 48).

Application of the bandwidth criterion is illustrated by a typical Bode plot shown in Figure D3. As defined, the phase margin bandwidth, ω_{BW_P}, was that frequency where the phase was 45 degrees more than -180, or -135 degrees. The gain margin bandwidth, ω_{BW_G} , was defined as that frequency where the gain was 6 dB more than the gain at a phase of -180 degrees. Therefore, ω_{BW} for this example was equal to ω_{BW_G}.

As illustrated in Figure D3, the line defining ω_{BW_G} could either intersect the magnitude curve at one, two, or three locations depending on the location of ω_{180}. The bandwidth with the lowest frequency would be the most conservative choice and would be the frequency reached first as the pilot's gain ramped up. On the other hand, one bandwidth will have the smallest phase margin and thus, will be the least stable. MIL-STD-1797A also states bandwidth "is the highest frequency at which the phase margin is at least 45 degrees and the gain margin is at least 6 dB; both criteria must be met." (Reference 3, page 226) It is this former bandwidth which was identified as the ω_{BW_G}.

The bandwidth criterion also required the calculation of the system's high frequency phase delay. This phase delay could accurately be modeled by a pure time delay of the form $e^{-\tau_\Theta s}$, where τ_Θ was the system's high frequency time delay. By approximating the phase curve of the open-loop Bode plot as having a constant slope beyond ω_{180} it is easily shown the time delay can be approximated by:

$$\tau_\Theta \approx \tau_P = \frac{\phi 1 - 180°}{57.3\omega 1} \tag{D3}$$

where ω_{180} is the frequency where the phase angle is 180°, $\omega_1 = 2\omega_{180}$, and ϕ_1 is the phase at this frequency (Reference 3, page 228).

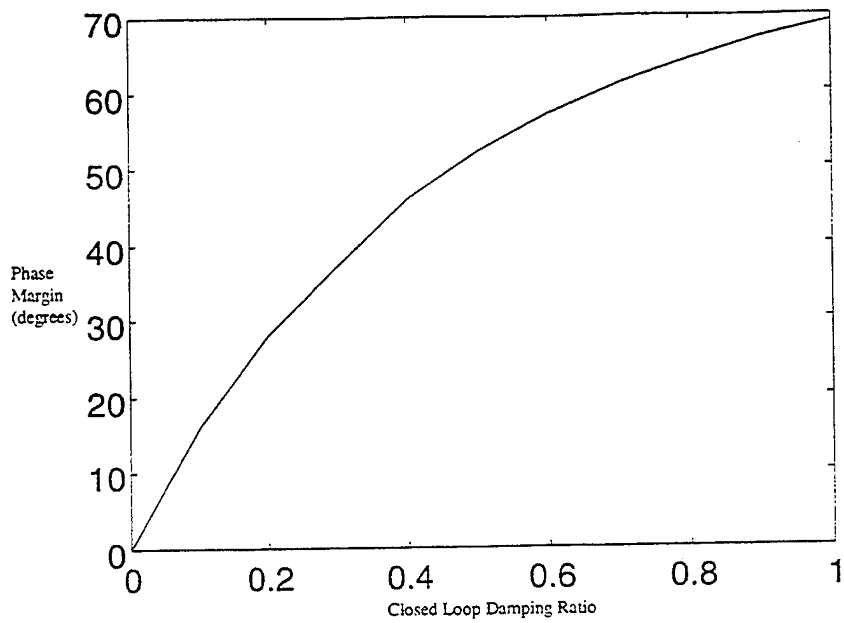


Figure D2 Relationship of Phase Margin to Closed-Loop Damping for $G(s) = Ke^{-\tau s}/s$

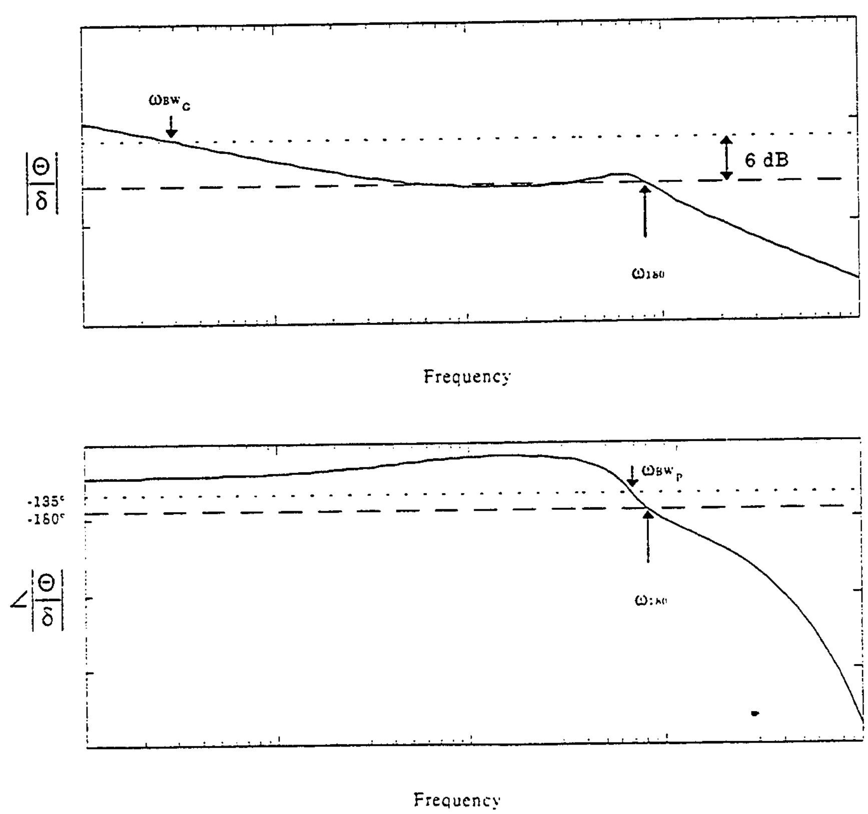


Figure D3 Definition of ω_{BW} from the Open-Loop Frequency Response

The longitudinal bandwidth criterion is shown in Figure D4 for aircraft in the landing phase of flight. This figure shows boundaries which are currently in MIL-STD-1797A (solid lines) and new bandwidth boundaries which are recommended for inclusion in the next revision of MIL-STD-1797 (dashed lines). The proposed bandwidth boundaries are valid only when applied along with the dropback criterion. Again, handling qualities levels correspond to the Cooper-Harper Pilot Rating scale.

From a pilot's point of view, aircraft with high bandwidths tend to have crisp, rapid, and well damped responses while aircraft with low bandwidths tend to wallow and have sluggish responses (Reference 2, page 49). In contrast to the proposed boundaries, historical flight test results indicate there is an upper limit on bandwidth. As ω_{BW} is increased beyond 4 to 5 radians/second, pilots have difficulty controlling the aircraft along the desired flightpath in the presence of disturbances. If the aircraft does not attenuate frequencies above this range, pilots may rate the aircraft's handling qualities as being poor. As will be shown in the next section, application of the dropback criterion indirectly sets an upper limit on ω_{BW}.

DROPBACK CRITERION

The dropback criterion, as defined in References 4 through 7, has been recommended for inclusion in MIL-STD-1797A augmenting the proposed boundaries of the bandwidth criterion (see dashed boundaries on Figure D4). This new dropback criterion

> "...was a measure of the mid-frequency response to attitude changes.... Excessive dropback results in pilot complaints of abruptness and lack of precision in pitch control—complaints common also to aircraft with excessive values of pitch attitude bandwidth." (Reference 5, page 22)

As seen in Figure D5, the dropback criterion was based upon the time response of an aircraft due to a pitch manipulator input. The criterion required a step pitch manipulator input be applied until a steady-state pitch rate, q_{ss}, was reached; then the input was taken out. The maximum pitch rate, q_{peak}, was defined to be the maximum pitch rate attained during the input phase. Dropback, (Drb), was defined to be the difference between the maximum pitch attitude and the steady state pitch attitude once the input was taken out. Both Drb and q_{peak} were normalized by q_{ss} so there was no dependency on the length of input. Note that dropback was independent of the system's time delay, τ_θ.

Historical flight test results show that when the normalized values, q_{peak}/q_{ss} and Drb/q_{ss}, are plotted onto Figure D5b a correlation in pilot opinion exists. If the data point lied above the line, excessive dropback existed indicating an abruptness or lack of pitch attitude precision. In the areas of excessive dropback, the criterion required adding one to the level predicted by the bandwidth criterion using the proposed boundaries. Correlation of pilot opinion was not strong enough to warrant usage of the dropback criterion alone, however when coupled with the bandwidth criterion, historical data show correlation of pilot opinion increases.

Studies show the dropback criterion accounts for poor handling qualities due to high ω_{BW}'s. As stated before, pilots have difficulties controlling aircraft with high ω_{BW}'s in the presence of disturbances since high frequencies are not attenuated. This was the justification for removing the "Abruptness Limit" in MIL-STD-1797A's bandwidth definition as shown in Figure D4.

In conclusion, the CAP and bandwidth criteria can be used to help predict pilot opinion of an aircraft in the landing phase of flight. CAP was based upon the aircraft's true airspeed, high frequency zero, short period natural frequency, and short period damping ratio. The bandwidth criterion, when coupled with the dropback criterion, was based upon the aircraft's open loop frequency and time responses. When applied separately, each criterion had reasonable correlation to historical pilot opinion, however, they did not predict the same pilot opinion over all possible aircraft responses.

RESULTS OF MAPPING THE CAP DOMAIN ONTO THE BANDWIDTH DOMAIN

To determine those areas where the CAP, bandwidth, and bandwidth with dropback agreed, the CAP domain was mapped onto the bandwidth domains. Mapping in the other direction, or mapping the bandwidth domains onto the CAP domain, would result in five equations and four unknowns—resulting in zero, one, or many solutions.

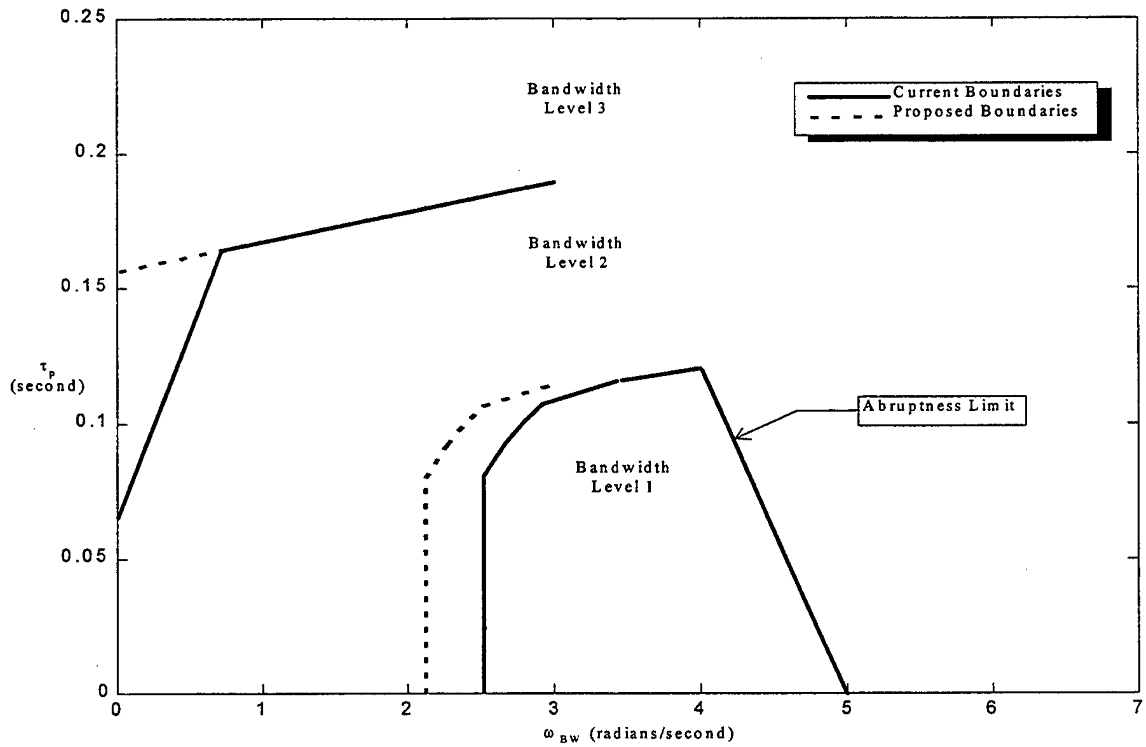
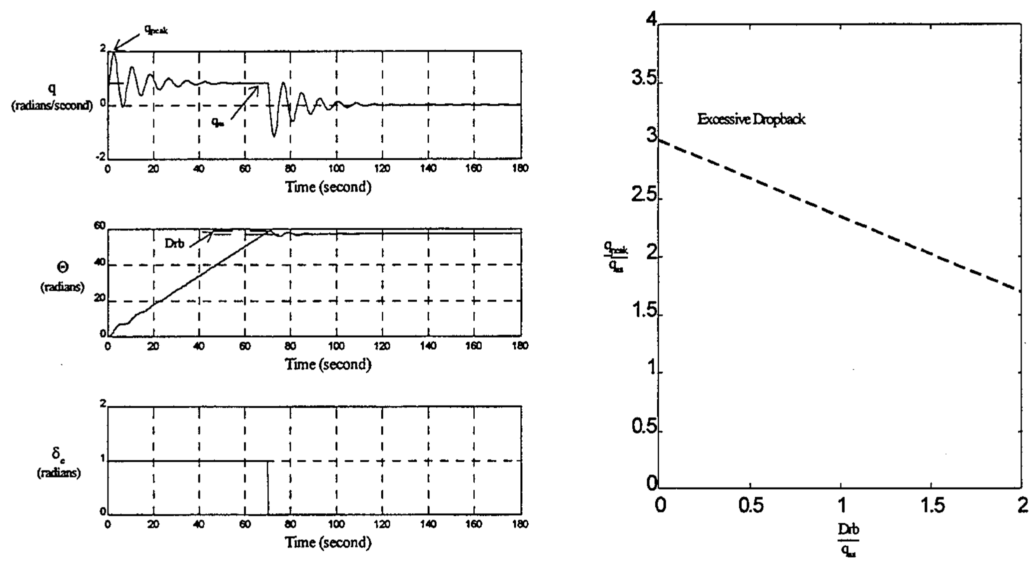


Figure D4 Landing Phase Bandwidth Criterion



(a) (b)

Figure D5 Dropback Criterion Definition

Because of this non-uniqueness, mapping of the bandwidth domains onto the CAP domain was not accomplished.

To map the CAP domain onto the bandwidth domains, K_Θ, $1/T_{\Theta_2}$, and τ_Θ must be specified making Equation D2 unique—ω_{sp} and ζ_{sp} are specified due to the location in the CAP domain using Equation D1. Due to the definition of bandwidth, K_Θ is independent of bandwidth and does not influence the solution. The variables $1/T_{\Theta_2}$ and τ_Θ were selected as nominal values for VISTA in the approach and landing configuration (Landing Gear - DOWN, Speed Brakes - OUT), 2,300 feet pressure altitude (PA), and 170 Knots True Airspeed (KTAS) and are shown in Table D3. With these nominal values the pitch attitude transfer function, Equation D2, was unique for each point in the CAP domain. Thus, each specific point in CAP defined a point in the bandwidth and dropback domains.

Table D3
NOMINAL VALUES OF $1/T_{\Theta_2}$
AND τ_Θ FOR VISTA

$1/T_{\Theta_2}$	τ_Θ (sec)
0.51	0.100

The CAP Level 1, as specified by points A, B, C, and D in Figure D6, mapped onto the bandwidth domain as shown in Figure D7 and the bandwidth domain augmented by the dropback criterion as shown in Figure D8. Note the $\omega_{sp}|_{min}$ area in Figure D6 for both Level 1 and 2 was defined from Table D1. If an aircraft fell within the shaded region of Figure D6, the predicted level automatically increased to the next higher level—Level 2 or 3, respectively.

Note the scale in Figure D7 was magnified to show the area of interest as related to Figure D4. The vertical lines are those lines which delineate bandwidth Level 1, 2, and 3. The shaded region shows the area where CAP Level 1 agreed with bandwidth Level 1.

Figure D8 shows the same magnification as Figure D7. However, in this figure, the new dropback boundaries are used along with application of the dropback criterion. Comparing Figure D7 to Figure D8 reveals that application of the dropback definition significantly decreased the area where CAP Level 1 agreed with the bandwidth domain. Note that in both Figures D7 and D8, all CAP Level 1 points are phase limited as defined by the bandwidth criterion.

Mapping CAP Level 2 onto the bandwidth domain was not as straight forward as that for CAP Level 1. Due to the definition of bandwidth, a non-linear "Jump Line" existed as shown in Figure D6. This line resulted from ω_{BW_G} on the Bode plot, see Figure D3, jumping from the local peak near ω_{sp} to a lower ω_{BW_G} as a result of where the 6 dB gain line fell. Two conditions must be met for this discontinuity to exist. First, the bandwidth must be gain margin limited. Secondly, the pitch attitude to pitch manipulator magnitude Bode plot must be non-monotonic—as shown in Figure D3. In other words, the slope of the Bode magnitude with respect to frequency must change signs resulting in a "shelf" type Bode magnitude plot shown in Figure D3. The dashed region in Figure D9 shows those areas where conditions allow the Jump Line to exist. Using Newton's non-linear solution technique, it can be shown there was one jump line for the CAP Level 2 region as shown in Figure D9.

As a result of the Jump Line, the closed CAP region EFJKLE shown in Figure D6 mapped onto the respective closed region in bandwidth shown in Figure D10. Similarly, the closed CAP region GHIG mapped onto the respective closed region in bandwidth shown in Figure D11. However, mapping across the Jump Line resulted in an open region in the bandwidth domains. For instance, the closed CAP region FHJF mapped onto an open region in bandwidth which contained a discontinuous jump.

Mapping CAP Level 2 onto the bandwidth domain using the dropback criterion resulted in Figures D12 and D13. Once again, including the dropback criterion changed those areas where the criteria agreed with one another. As shown in Figure D12, application of the dropback criterion resulted in the same areas of agreement as the bandwidth criterion for high bandwidths. Above approximately a bandwidth of 5 radians/second, the dropback criterion increased the bandwidth to a Level 2 while the "Abruptness Limit" did the same resulting in agreement with CAP.

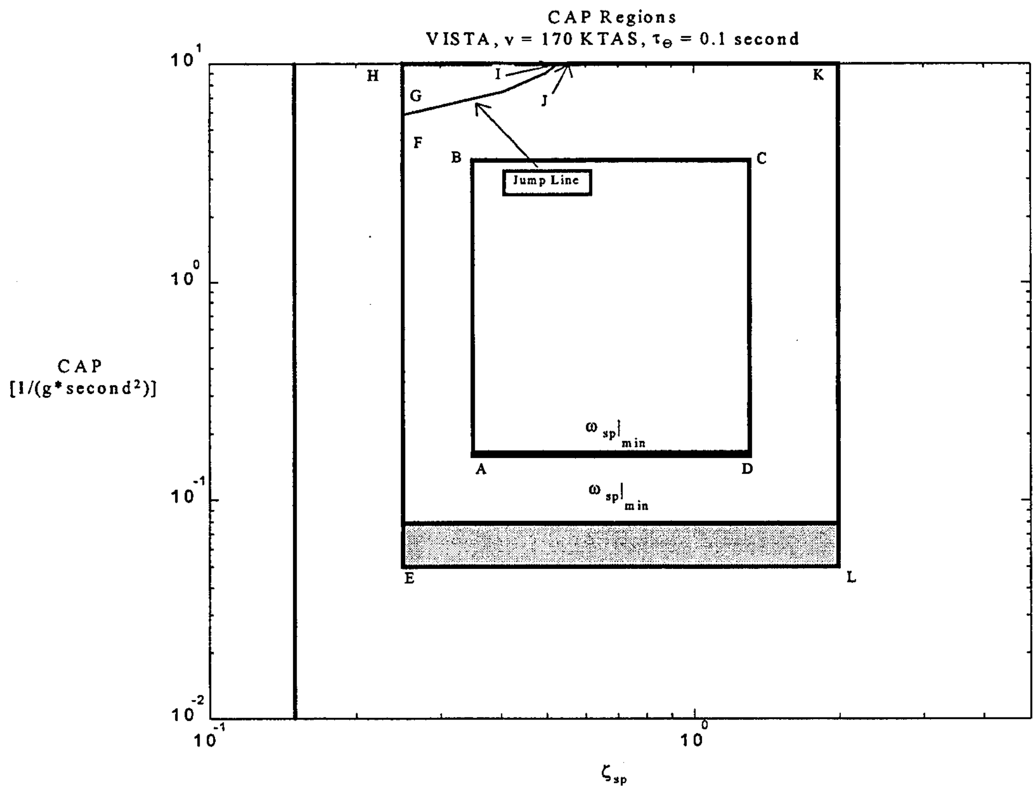


Figure D6 Area Map of CAP

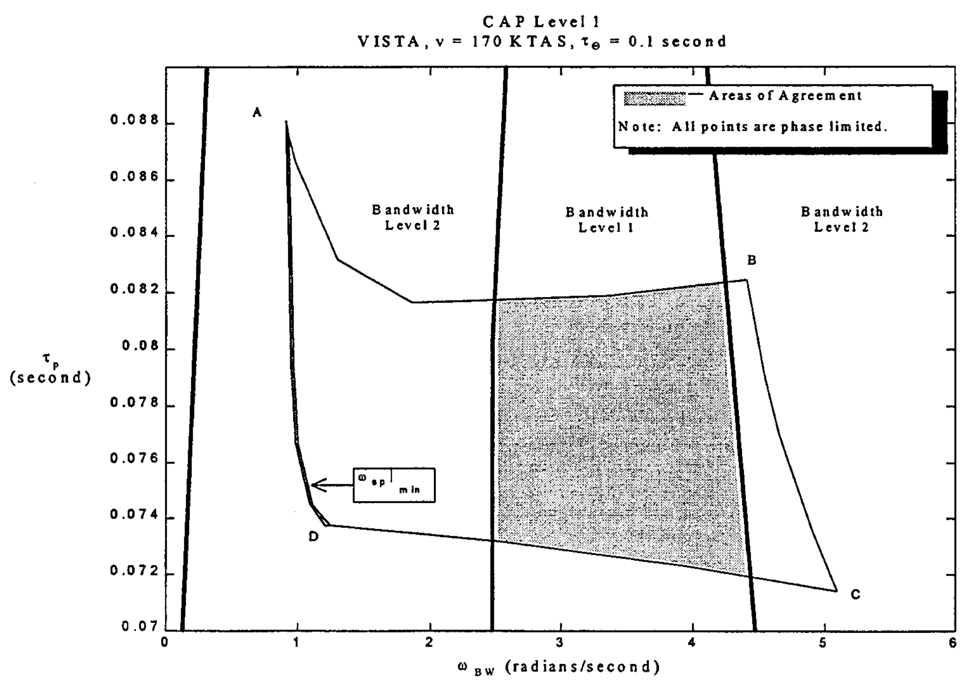


Figure D7 CAP Level 1 Mapped onto the Bandwidth Domain

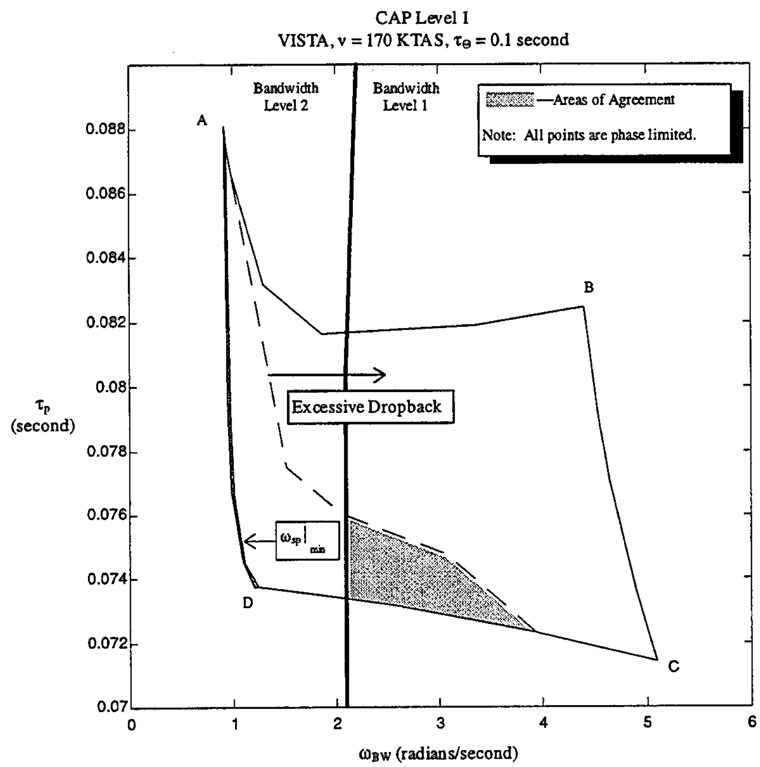


Figure D8 CAP Level 1 Mapped onto the Bandwidth Domain With Dropback

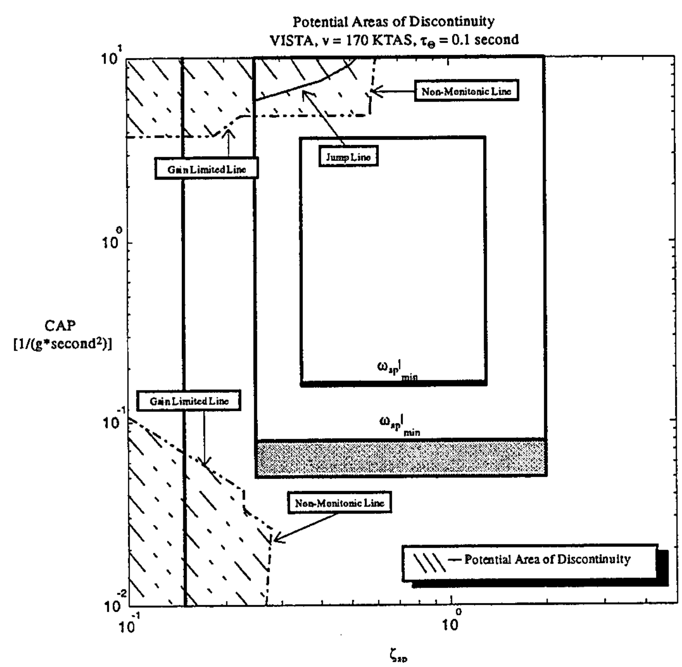


Figure D9 Potential Areas of Discontinuity in CAP

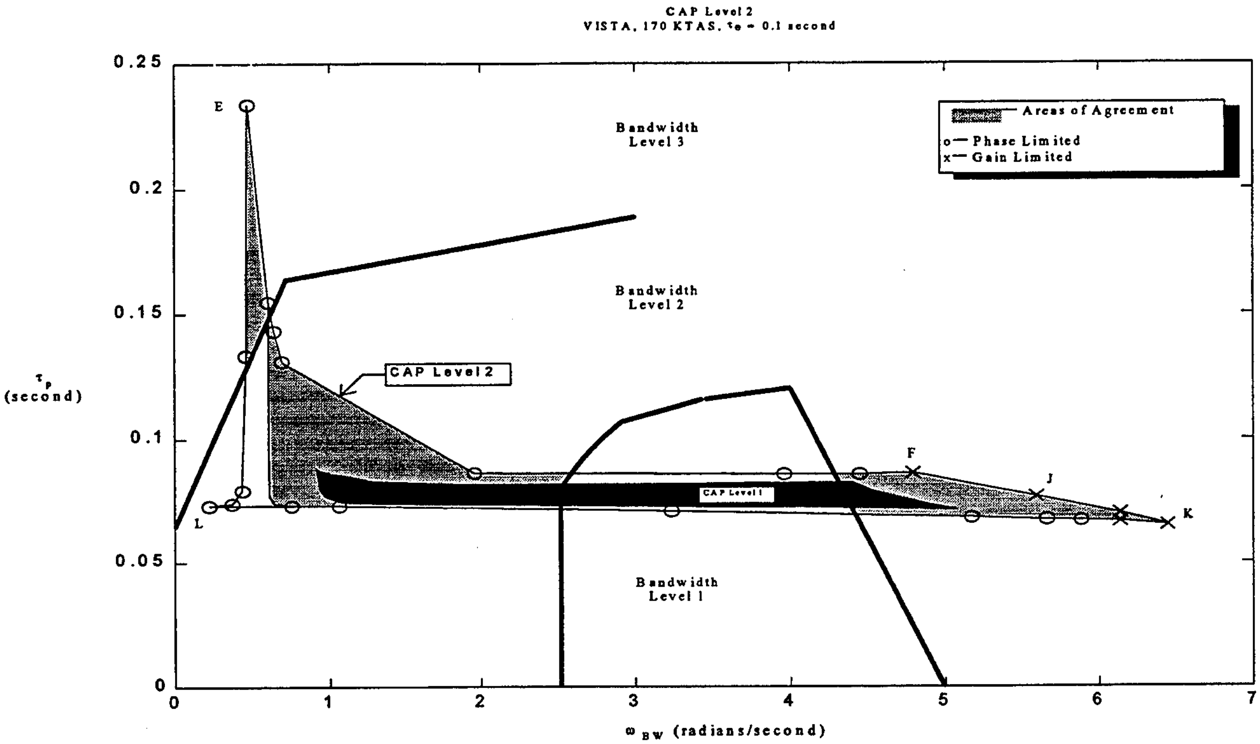


Figure D10 CAP Level 2 Mapped onto the Bandwidth Domain

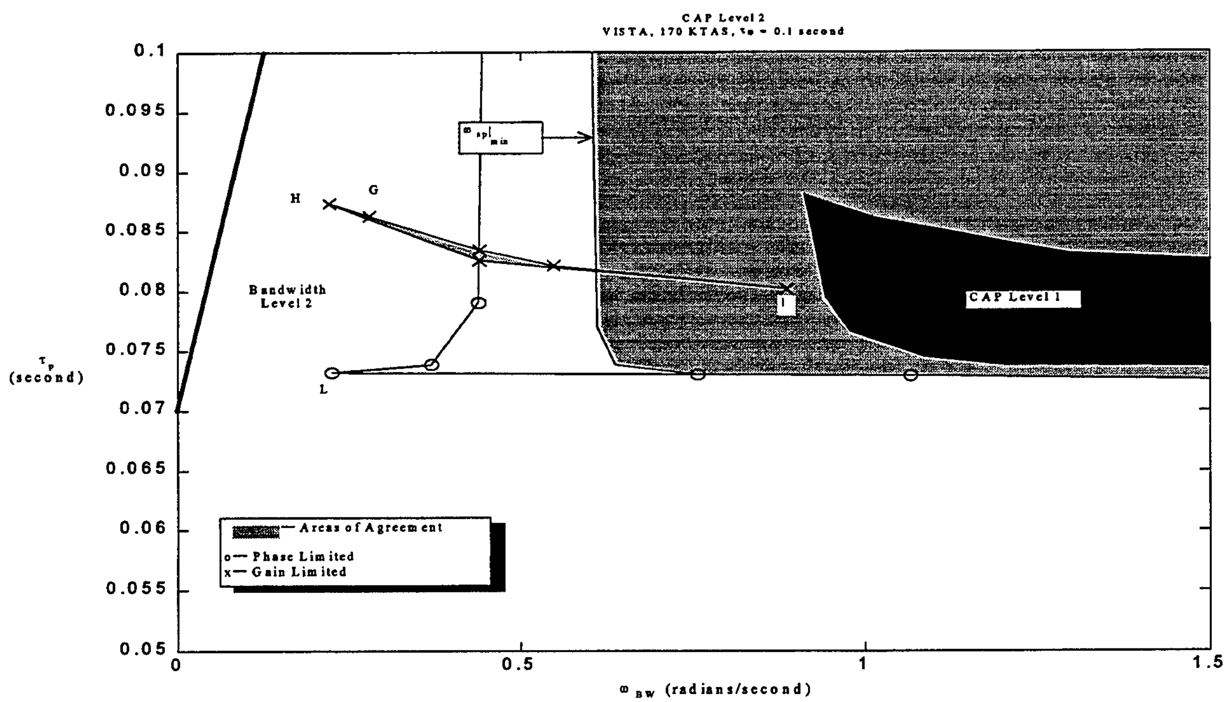


Figure D11 CAP Level 2 Mapped onto the Bandwidth Domain

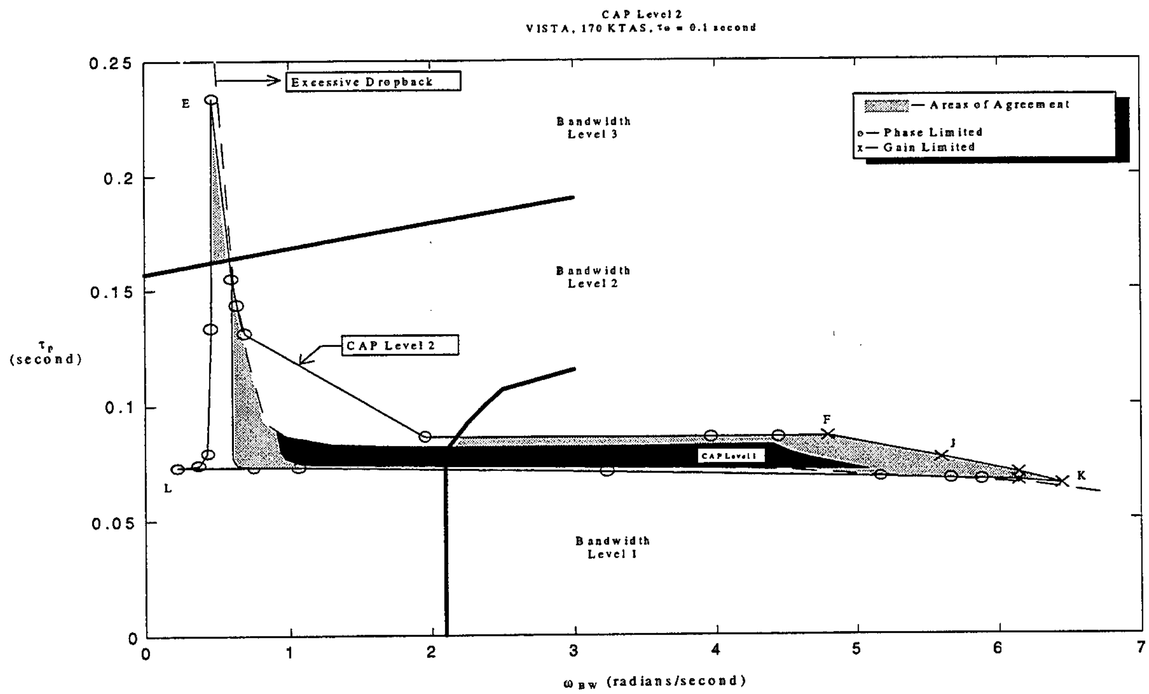


Figure D12 CAP Level 2 Mapped onto the Bandwidth Domain—Jump Area

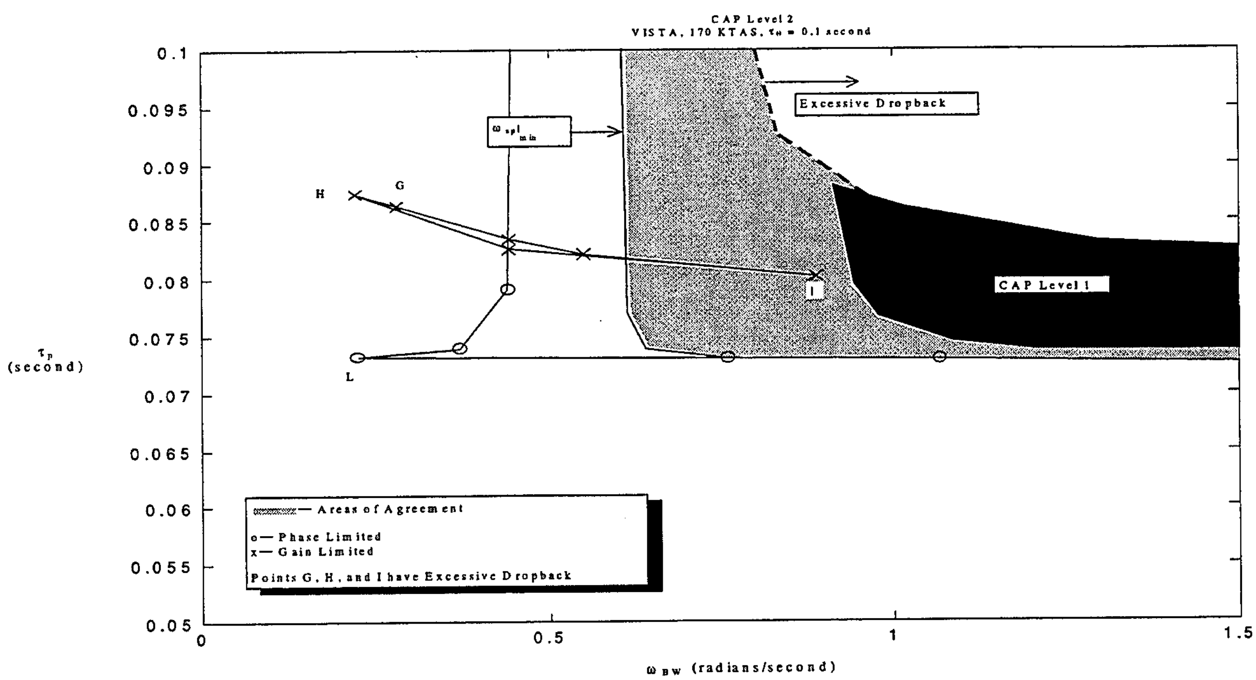


Figure D13 CAP Level 2 Mapped onto the Bandwidth Domain With Dropback

Above a bandwidth of 2.2 radians/second, the dropback criterion increased the area of agreement between the CAP and bandwidth domains. As shown in Figure D10, for aircraft which lied above the CAP Level 1 region in the bandwidth domain and between a bandwidth of 2.5 and 4.5 radians/second, the bandwidth criterion alone predicted a Level 1 aircraft while CAP predicted a Level 2 aircraft. Applying the dropback criterion to the bandwidth domain, as shown in Figure D12, resulted in both criteria predicting a Level 2 aircraft. Both bandwidth and bandwidth with dropback predicted aircraft which lied below the CAP Level 1 region with a bandwidth above the Level 1 boundary bandwidth and below 4.5 radians/second to have Level 1 handling qualities while CAP predicted Level 2 handling qualities. The dropback criterion decreased the area of agreement below a bandwidth of 2.2 radians/second as shown in Figure D12.

The region bounded by points GHIG mapped onto the closed area shown in Figures D11 and D13. Using bandwidth alone resulted in both CAP and bandwidth predicting a Level 2 aircraft shown in Figure D11. Using bandwidth with dropback resulted in a bandwidth Level 3 aircraft and a CAP Level 2 aircraft shown in Figure D13. Note points G, H, and I have excessive dropback even though they lie to the left of the excessive dropback line in the bandwidth domain. This was a result of the non-analyticity of the bandwidth domain.

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APPENDIX E

FLIGHT TEST BUILDUP PROCEDURES

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FLIGHT TEST BUILDUP PROCEDURES

HANDLING QUALITIES DURING TRACKING

The test aircraft was flown in the same configuration used on final approach during the landing tasks, gear - DOWN and speed brake - OUT. The standby reticle in the test aircraft was set so the flight path marker (FPM) was approximately coincident with the aircraft's roll axis, or 187 milliradians of depression at 11 degrees angle of attack. The target aircraft executed a 30 degree bank level turn at constant airspeed. The test aircraft gained cutoff to begin a slow closure on the target. The safety pilot assisted the evaluation pilot by helping maintain the airspeed with the throttle. The evaluation pilot chose a point on the target (i.e., tailpipe) and aggressively tracked that point to zero error with the 2 milliradian center pipper in the standby reticle. Tracking by the test aircraft was accomplished without the use of rudder. The tracking test was discontinued when the slant range reached 1,000 feet or when the evaluation pilot felt that sufficient handling qualities during tracking (HQDT) had been performed. When unacceptable handling qualities were encountered, separation was increased and the test point was terminated.

PITCH CAPTURE TASK

The pitch capture task was only flown if a predicted Level 3 variable stability system (VSS) configuration failed the HQDT test, but had been determined to be landable by CALSPAN, as shown in the decision tree in Appendix F, Figure F1. The aircraft was configured at the same flight conditions and the VSS set as described above in the HQDT setup. The evaluation pilot attempted to capture and hold a pitch angle of five degrees below level flight using the pipper in the standby reticle and then recaptured the level flight pitch attitude. This task consisted of aggressively trying to keep the pitch attitude within ±0.5 degrees of desired pitch attitude. The evaluation pilot noted any problems with gross acquisition of the pitch attitude. If the pilot noted any undesirable characteristics that would make the aircraft questionable in the landing task (such as a pilot induced oscillation (PIO) rating of 5 or 6, using the scale in Appendix C), the test point was not flown in the landing task, as depicted by the Decision Tree in Appendix F, Figure F1.

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APPENDIX F

FLIGHT TEST DECISION TREE

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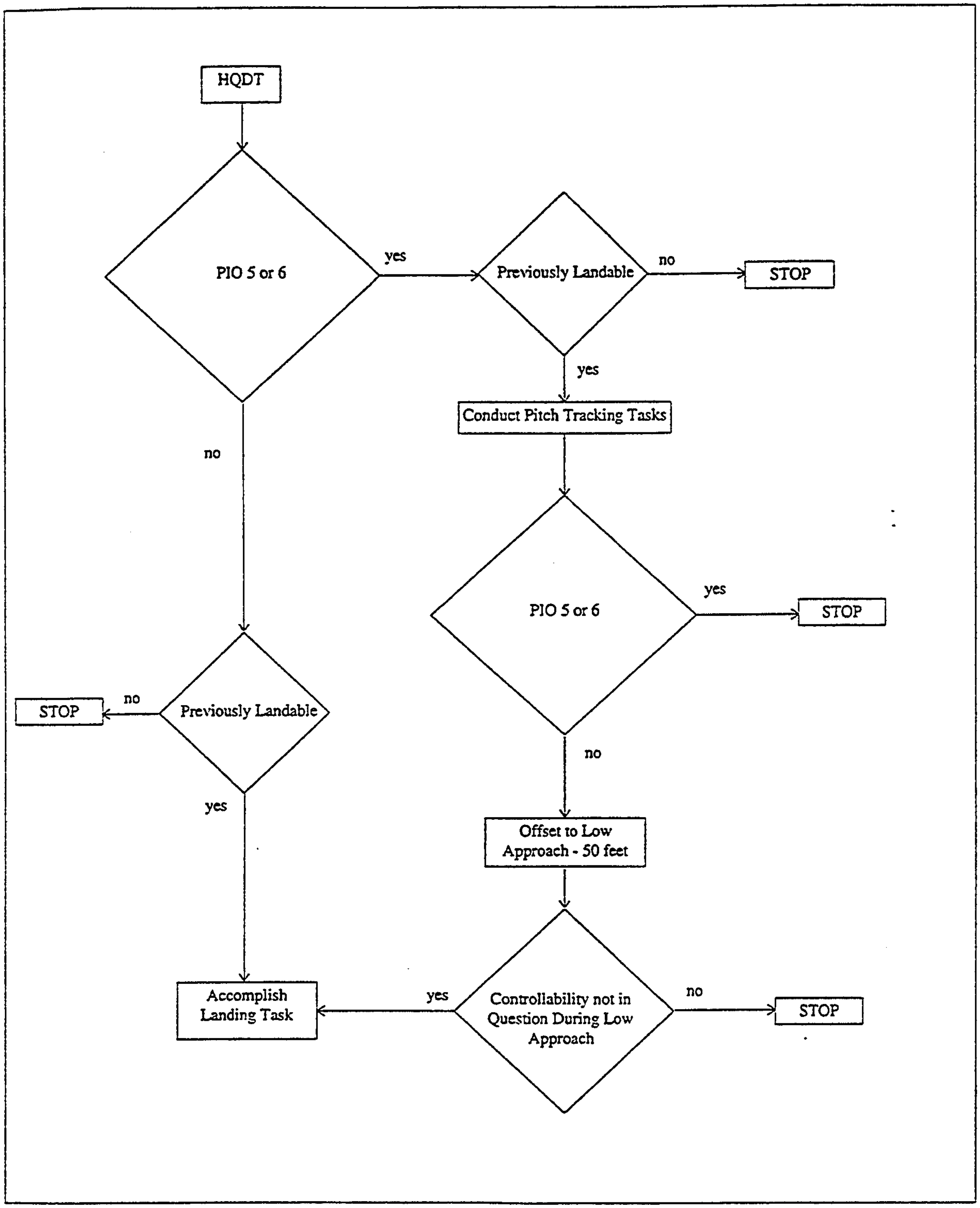

Figure F1 Flight Test Decision Tree

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APPENDIX G

RECORDED PARAMETERS

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Table G1
DATA AQUISITION SYSTEM PARAMETERS
RECORDED DURING TESTING

Parameter
Longitudinal stick displacement
Longitudinal stick force
Lateral stick displacement
Lateral stick force
Stabilator position (Left & Right)
Flaperon position (Left & Right)
Barometric Altitude
Barometric Altitude rate
True Airspeed
Calibrated Airspeed
Angle of attack, α
Pitch angle, θ
Pitch rate, q
Normal Load Factor at Center of Gravity, n_z
Fuel weight

Table G2
FLIGHT TEST DATA PARAMETERS
DERIVED FROM POSTFLIGHT ANALYSIS

Parameter
load factor per angle of attack, n/α
high frequency zero, T_{Θ_2}
Short Period Frequency, ω_{sp}
Short Period Damping, ζ_{sp}
Lower Order Equivalent Time Delay, τ_{Θ}
Gain Bandwidth, ω_{BW}
Phase Bandwidth, ω_{PH}
Estimation of Lower Order Equivalent Time Delay, τ_p
Dropback, Drb

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APPENDIX H

VISTA MODEL DEFINITIONS

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VISTA MODEL DEFINITIONS

VISTA MODEL DEFINITIONS

The following aircraft dynamic models were used during all flight tests. They were provided by the CALSPAN Corporation and were not validated by the HAVE CAP test team. These dynamic characteristics were optimized by CALSPAN to provide good flight control harmony over the wide range of short period dynamics. These models were held constant to facilitate consistency and repeatability for the full range of short period dynamics evaluated. It was recognized that these characteristics may not have provided the optimum control harmony for every variable stability system (VSS) configuration tested.

AIRCRAFT PHUGOID MODEL

The Variable-Stability In-Flight Simulator Test Aircraft's (VISTA) phugoid characteristics had a natural frequency of 0.023 radians per second, damping ratio of 0.2 and $1/T_{\theta_1}$ of 40 radians per second.

LATERAL-DIRECTIONAL AIRCRAFT MODEL

The VISTAs lateral-directional characteristics were a Dutch roll natural frequency of 1.94 radians per second and damping ratio of 0.24, and a roll mode time constant of 0.55 second with time delay of 0.14 second. This time delay was determined from the "maximum roll acceleration to half the input time history" method. The steady-state roll rate to roll controller force was 6.5 degrees per second per pound.

STICK DYNAMICS

The longitudinal center stick force gradient was 15 pounds per inch, while the lateral stick force gradient was set 10 pounds per inch. The longitudinal stick deflection to stick force transfer function was:

$$\frac{\delta_{es}}{F_{es}} = \frac{30^2}{15(s^2 + 2(0.7)(30)s + 30^2)} \qquad \text{(H1)}$$

The lateral stick deflection to stick force transfer function was:

$$\frac{\delta_{as}}{F_{as}} = \frac{30^2}{10(s^2 + 2(0.7)(30)s + 30^2)} \qquad \text{(H2)}$$

As seen from Equations H1 and H2, the center stick's damping ratio was 0.7 while the natural frequency was 30 radians per second.

ACTUATOR DYNAMICS

The VISTAs longitudinal actuator transfer function was, in degrees:

$$\frac{\delta_{e_{pos}}}{\delta_{e_{cmd}}} = \frac{1.8862x10^7 \cdot (s^2 + 2(0.03)(97)s + 97^2)}{(s^2 + 2(1.18)(63.3)s + 63.3^2)(s^2 + 2(0.57)(70.7)s + 70.7^2)(s^2 + 2(0.03)(94.2)s + 94.2^2)} \qquad \text{(H3)}$$

SIGN CONVENTION

Longitudinally, a positive pitch rate was defined by the rotation vector out the right wing resulting from a positive aft stick deflection and a negative horizontal stabilator deflection. Laterally, a positive roll rate was defined by the rotation vector out the nose resulting from a positive right stick deflection and positive aileron deflection. Directionally, a positive yaw rate was defined by the rotation vector through the bottom of the aircraft resulting from a positive rudder pedal deflection and a negative rudder deflection.

GROUND BASED SIMULATOR DEFINITIONS

The CALSPANs ground based simulation of the VISTA showed the aircraft's load factor per angle of attack (n/α) varied with fuel weight. Table H1 below shows $1/T_{\theta_2}$ and n/α for several fuel weights at 11 degrees angle of attack in the approach and landing configuration (Gear - DOWN, Speedbrakes - OUT). The high frequency zero, $1/T_{\theta_2}$, was calculated from:

$$\frac{1}{T\theta_2} \approx \frac{n}{\alpha} \cdot \frac{g}{V} \qquad \text{(H4)}$$

Table H1
GROUND BASED SIMULATOR LOAD FACTOR
PER ANGLE OF ATTACK AT DIFFERENT FUEL WEIGHTS

Fuel Weight (pounds)	True Airspeed (knots)	Calibrated Airspeed (knots)	n/α	$1/T_{\theta_2}$
8,092	180	167	4.0821	0.4370
6,050	173	161	4.2427	0.4550
4,522	169	157	4.3360	0.4650
3,570	166	154	4.4350	0.4757
2,000	161	149	4.5540	0.4880
952	159	147	4.7600	0.5100

Notes: 1. n/α: load factor per angle of attack
2. $1/T_{\theta_2}$: zero associated with short period approximation

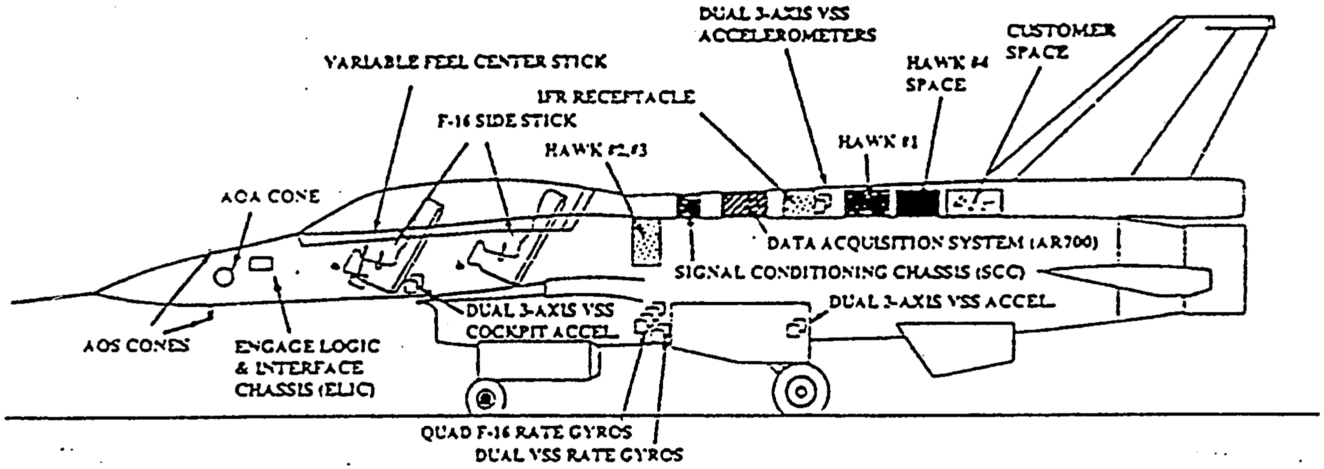

Figure H1 VISTA NF-16D Component Layout

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APPENDIX I

FLIGHT TEST DATA PLOTS

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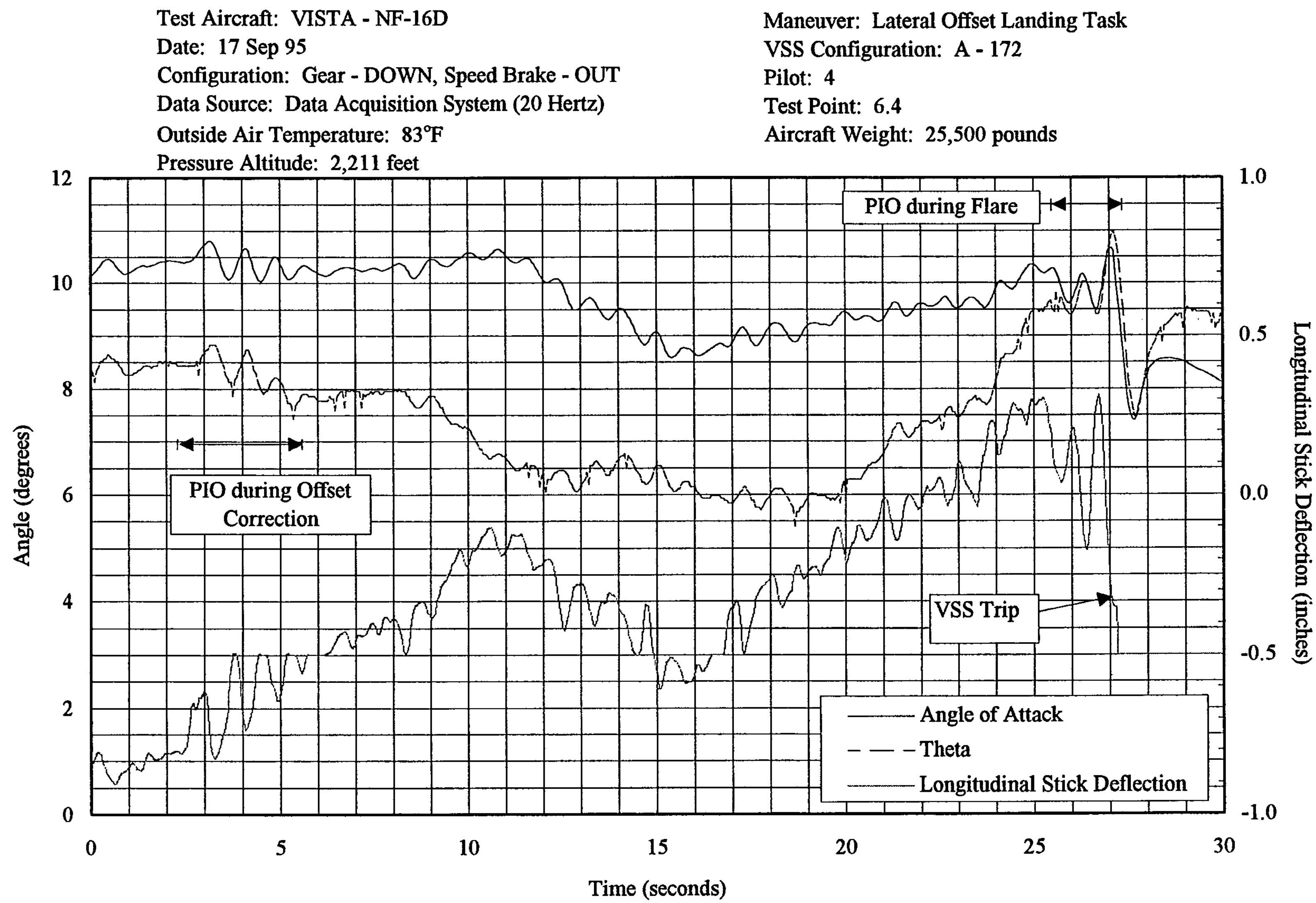

Figure I1 Longitudinal Stick Deflection Time Trace During PIO, Test Point 6.4

Test Aircraft: VISTA - NF-16D
Date: 17 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 83°F
Pressure Altitude: 2,211 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: A - 172
Pilot: 4
Test Point: 6.4
Aircraft Weight: 25,500 pounds

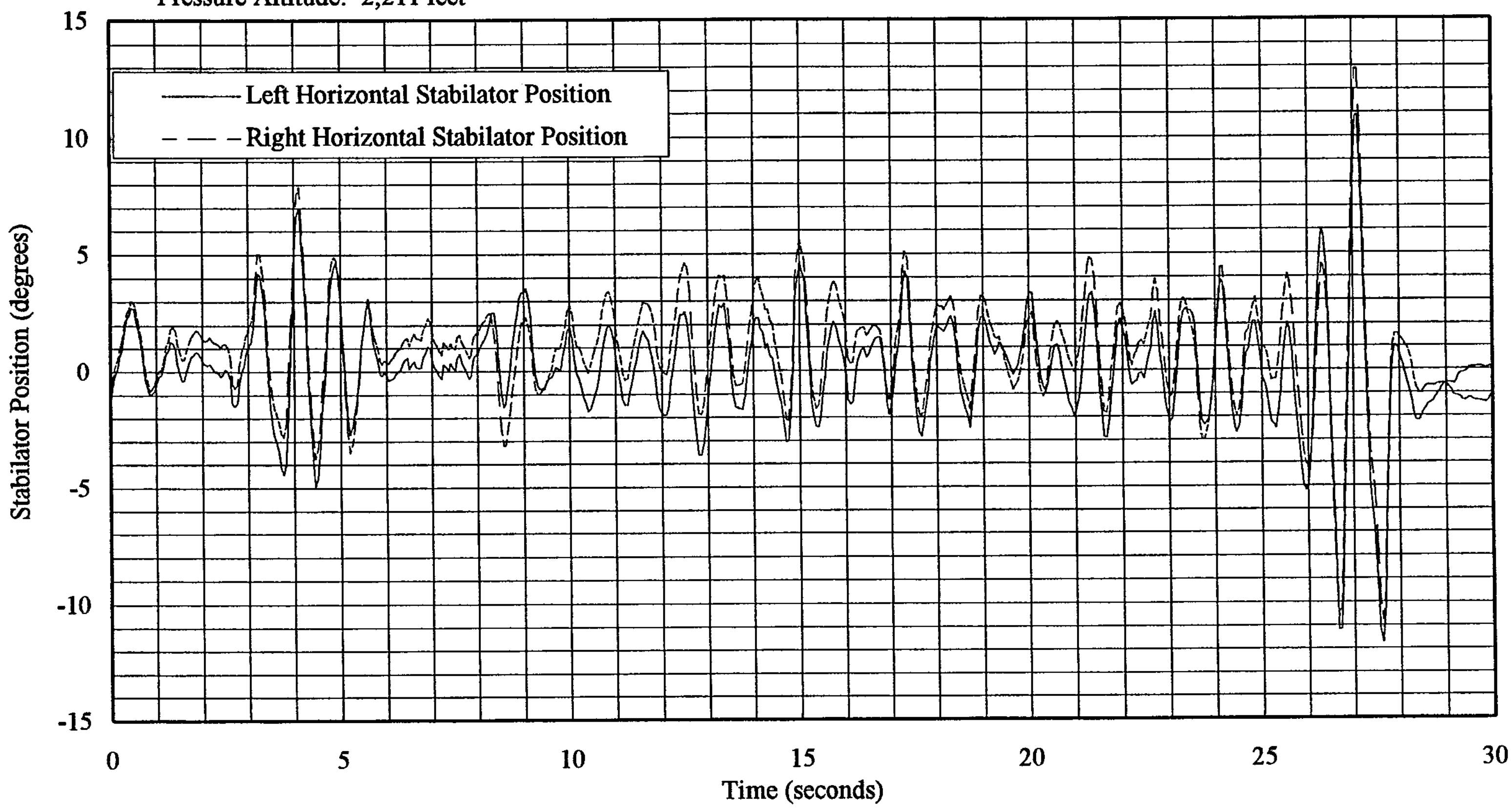

Figure I2 Stabilator Position Time Trace During PIO, Test Point 6.4

Test Aircraft: VISTA - NF-16D
Date: 17 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 83°F
Pressure Altitude: 2,211 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: A - 172
Pilot: 4
Test Point: 6.4
Aircraft Weight: 25,500 pounds

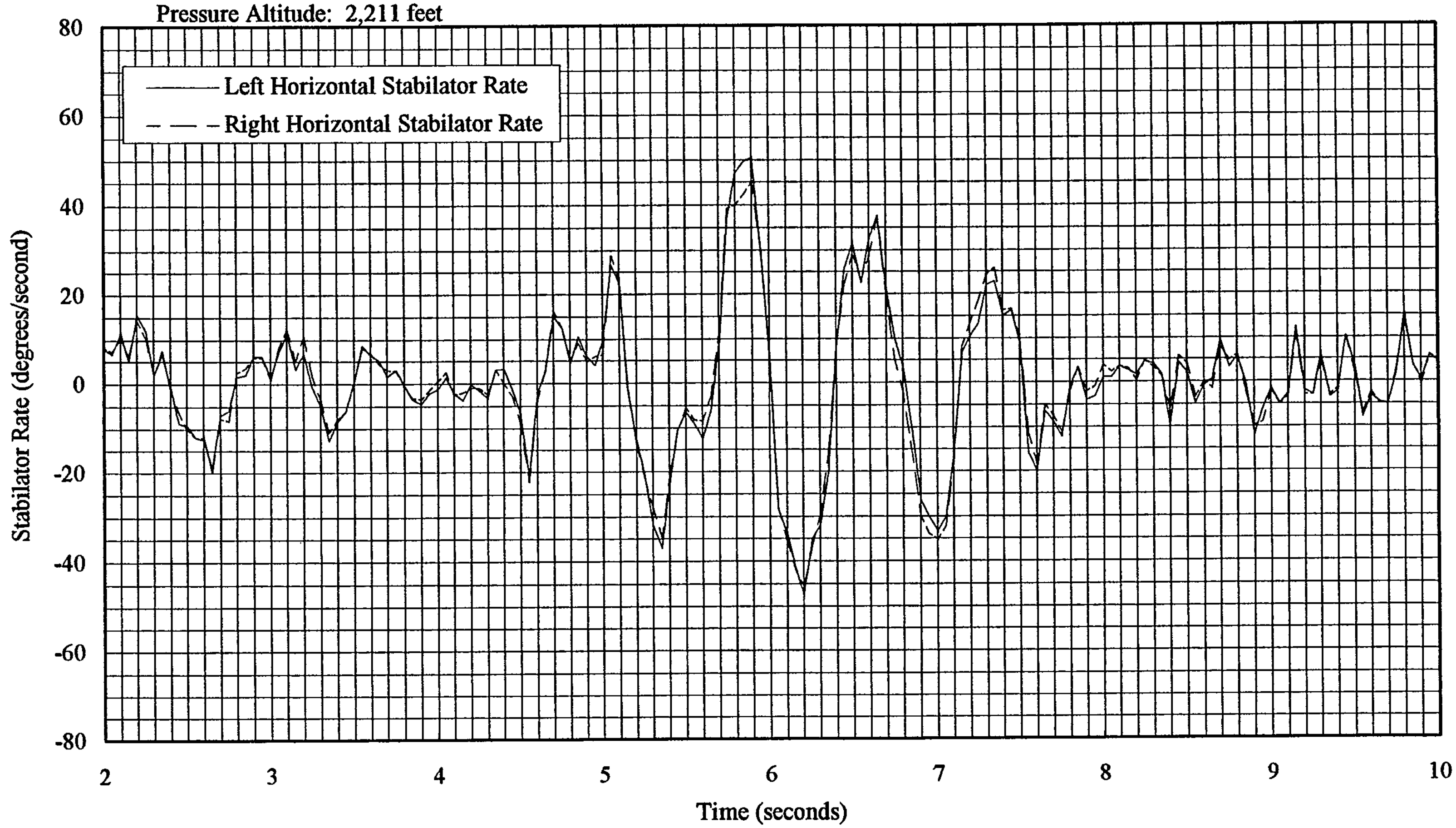

Figure I3 Stabilator Rate Time Trace Prior to PIO, Test Point 6.4

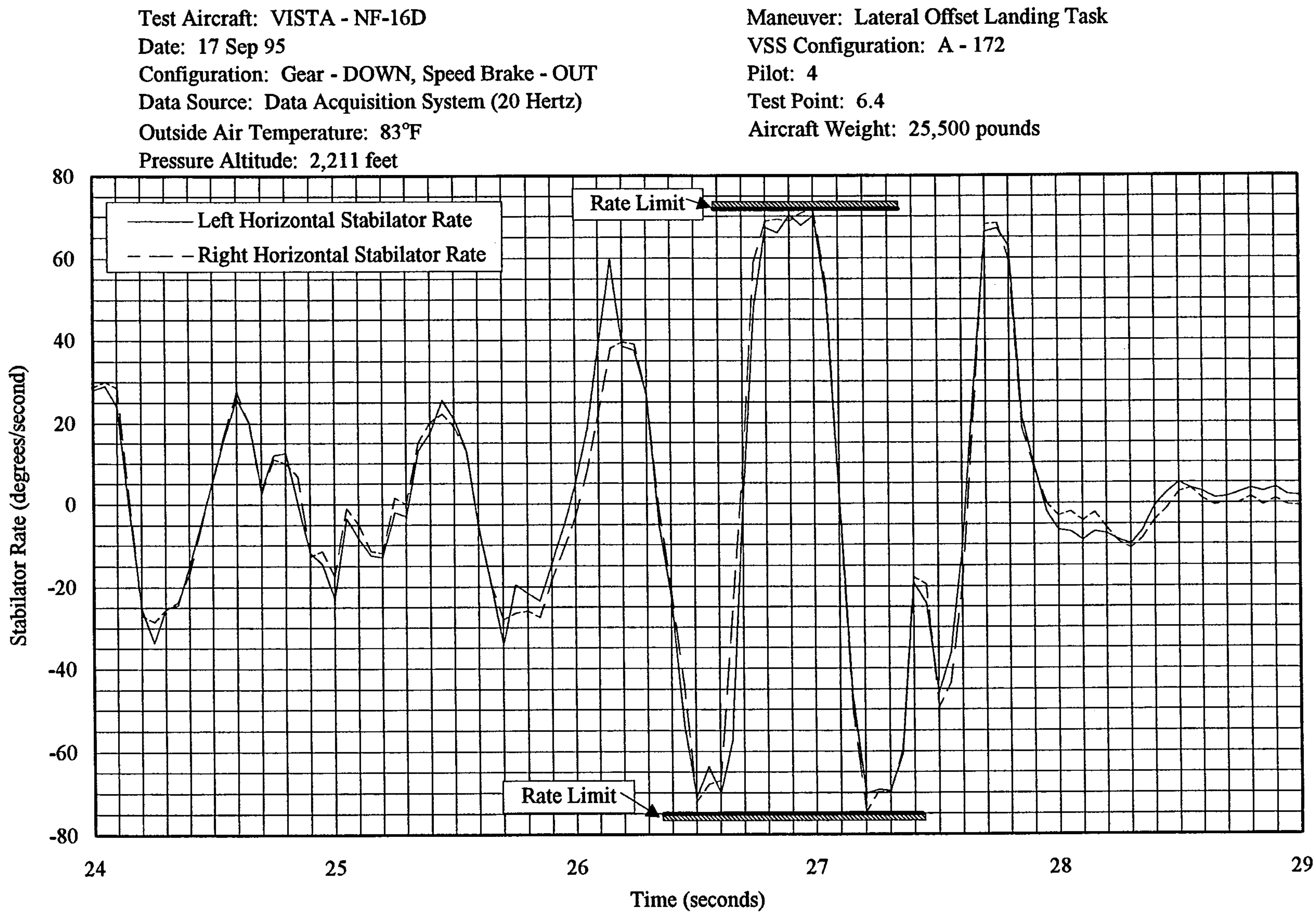

Figure I4 Stabilator Rate Time Trace with Rate Limiting During PIO, Test Point 6.4

APPENDIX J

SUPPLEMENTAL FLIGHT TEST DATA PLOTS

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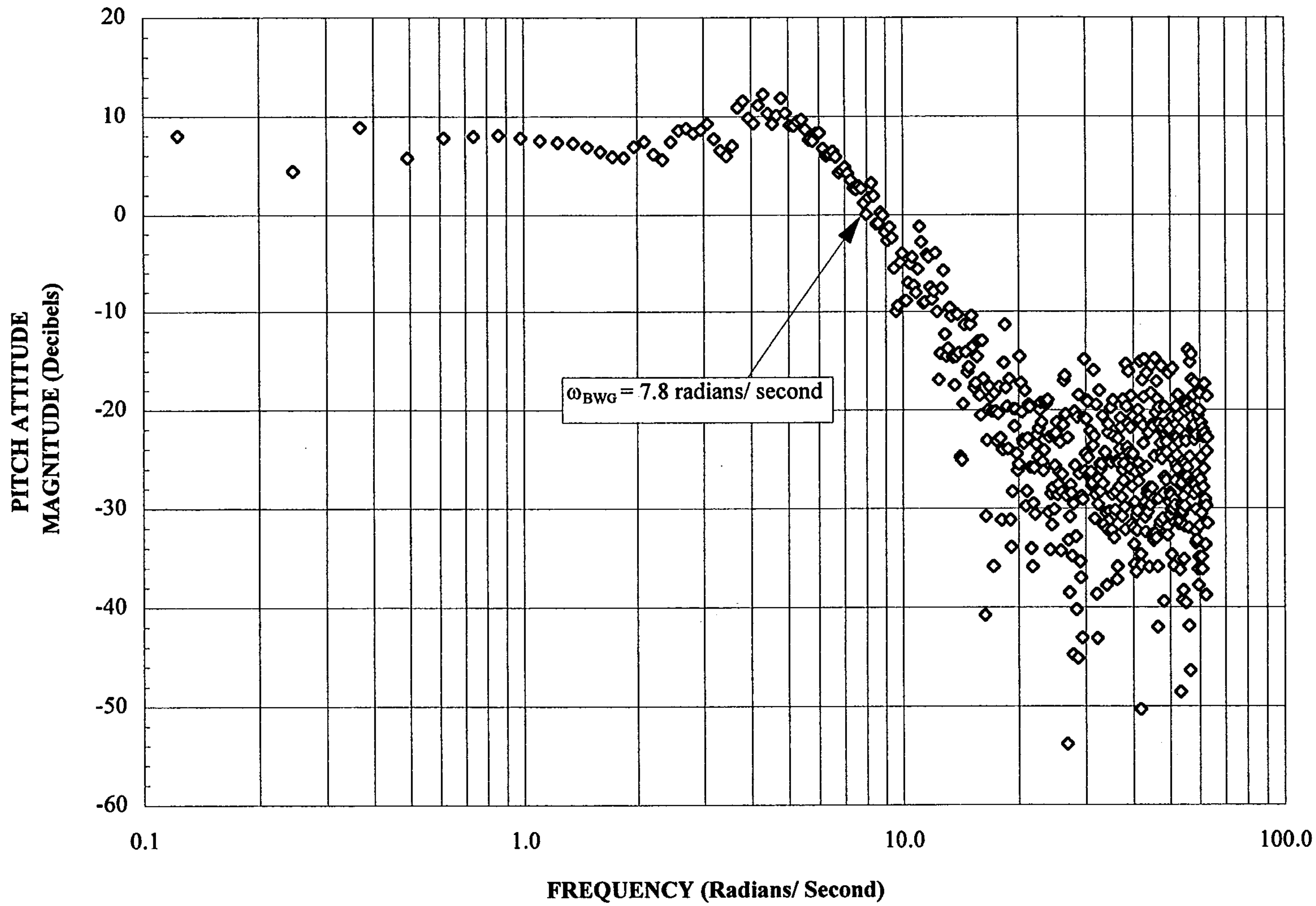

Figure J1 VSS Configuration A Magnitude Bode Plot

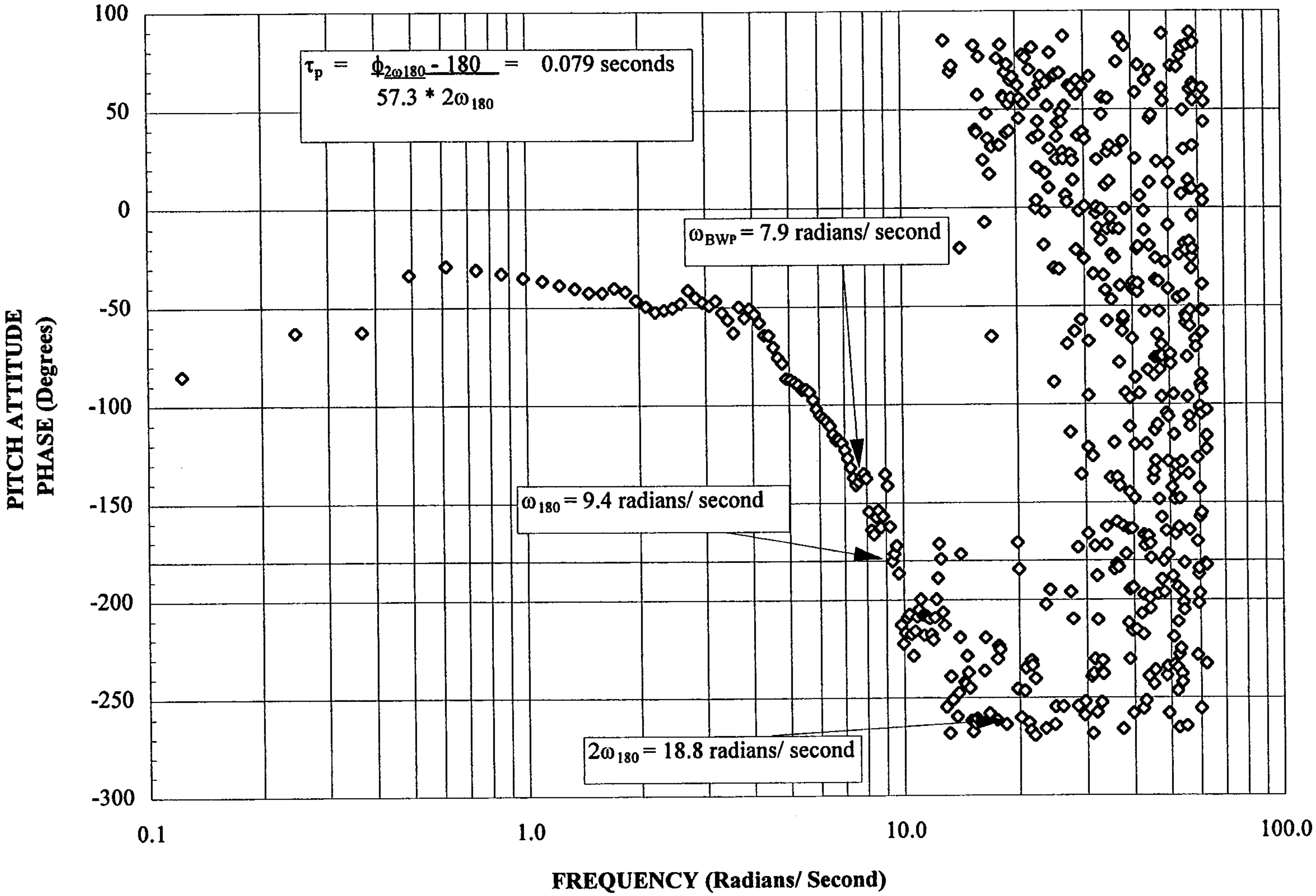

Figure J2 VSS Configuration A Phase Bode Plot

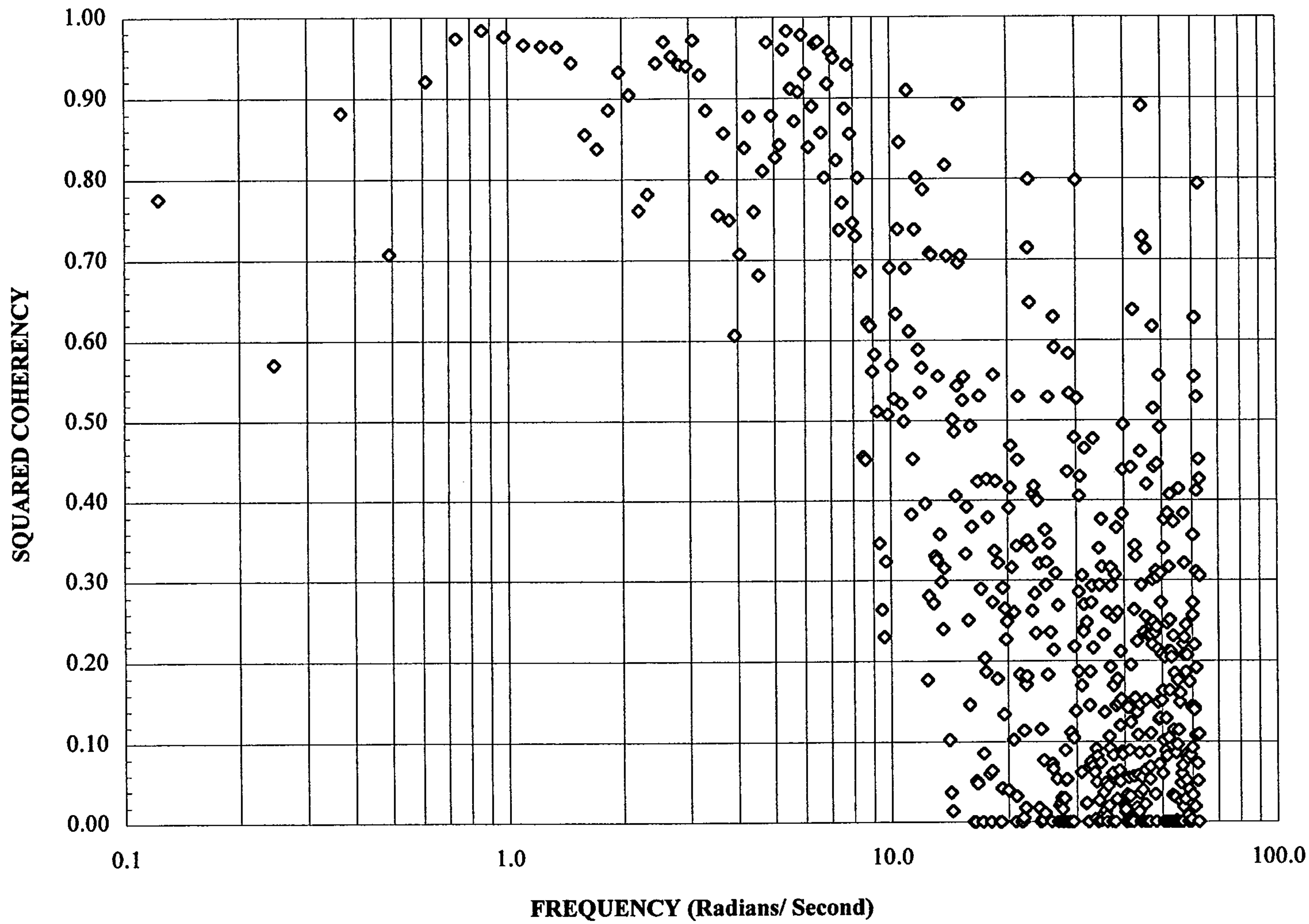

Figure J3 VSS Configuration A Bode Squared Coherency Plot

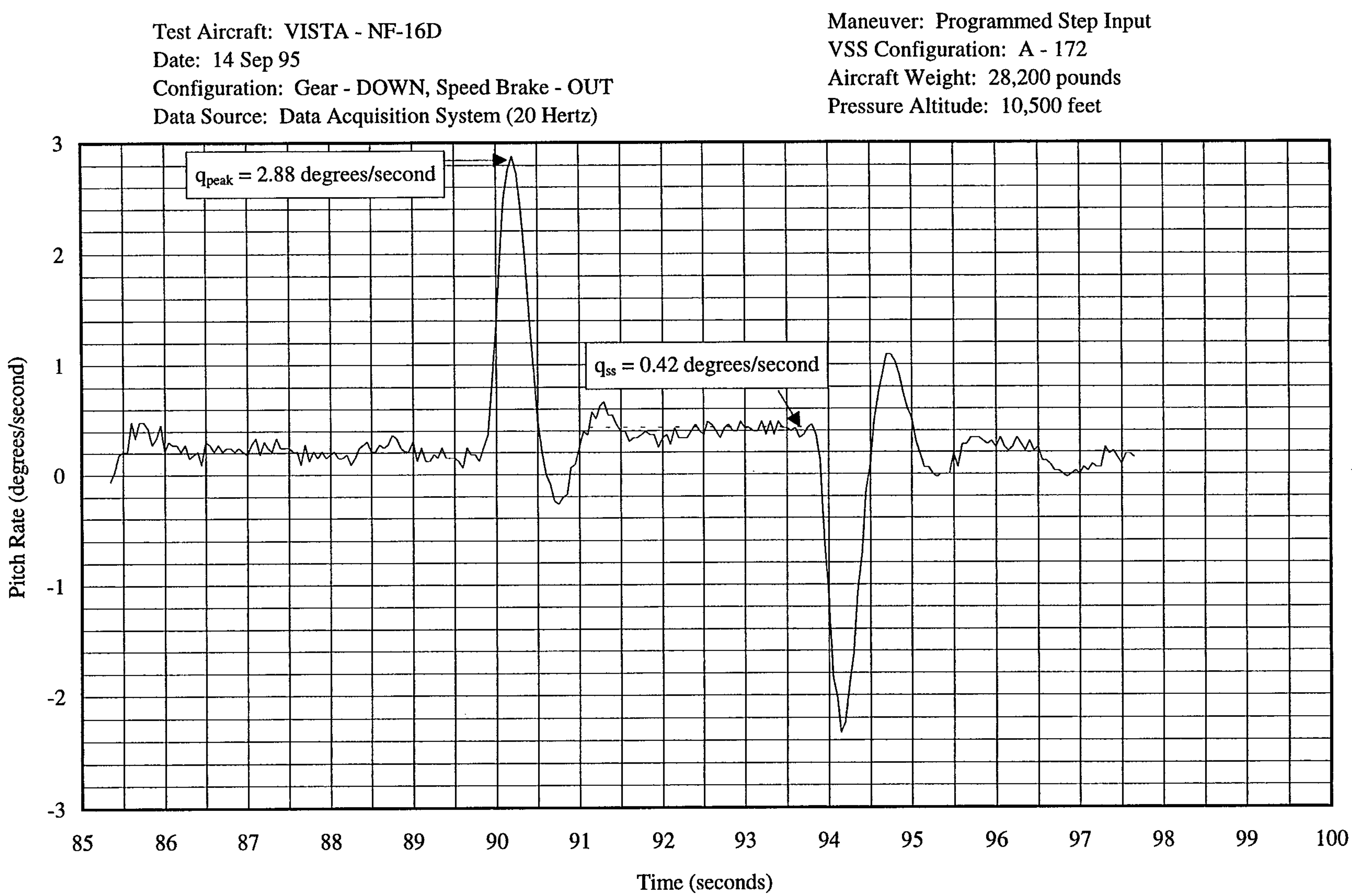

Figure J4 VSS Configuration A Pitch Rate Dropback

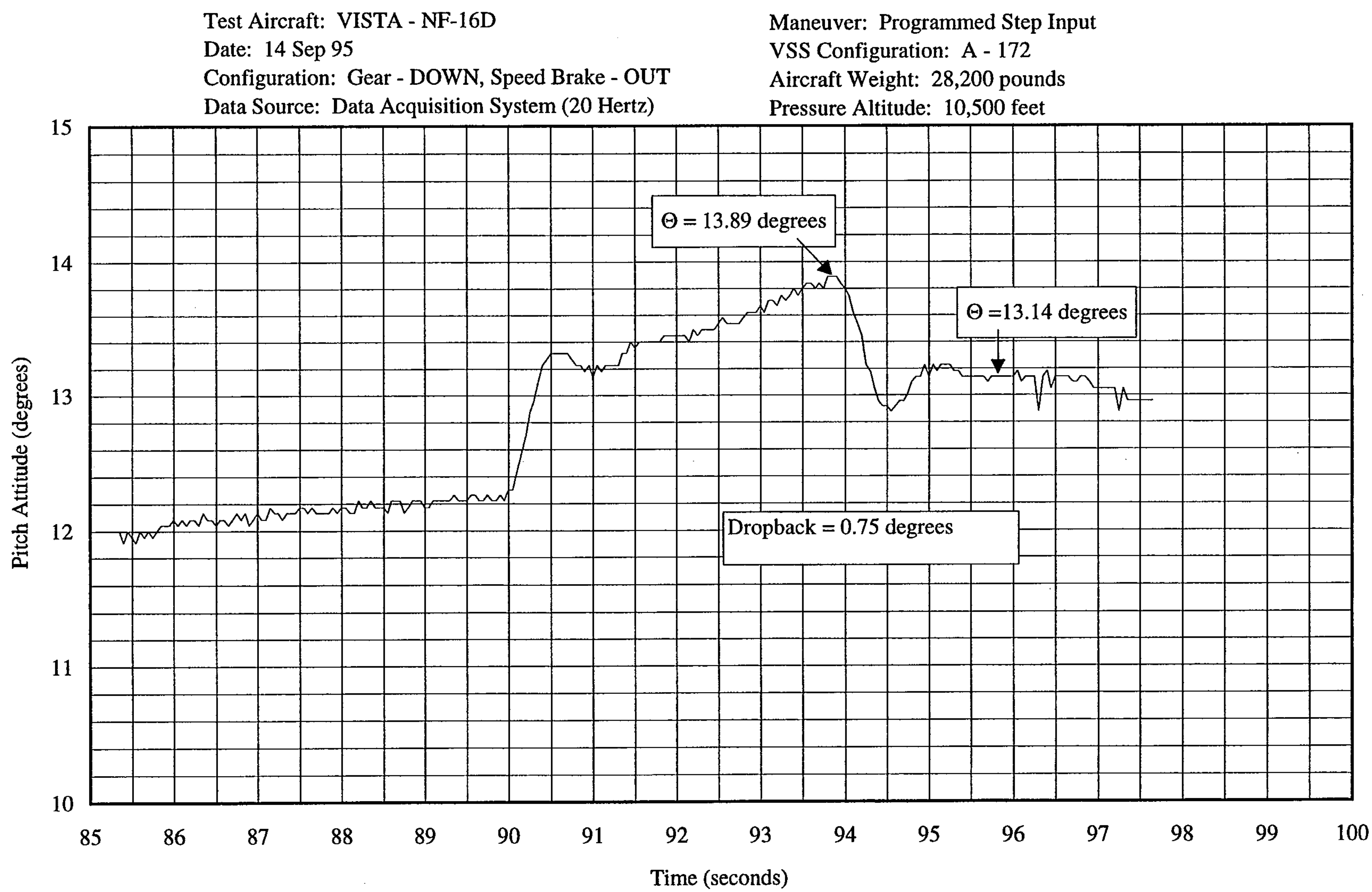

Figure J5 VSS Configuration A Pitch Angle Dropback

Test Aircraft: VISTA - NF-16D
Date: 14 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)

Maneuver: Programmed Step Input
VSS Configuration: A - 172
Aircraft Weight: 28,200 pounds
Pressure Altitude: 10,500 feet

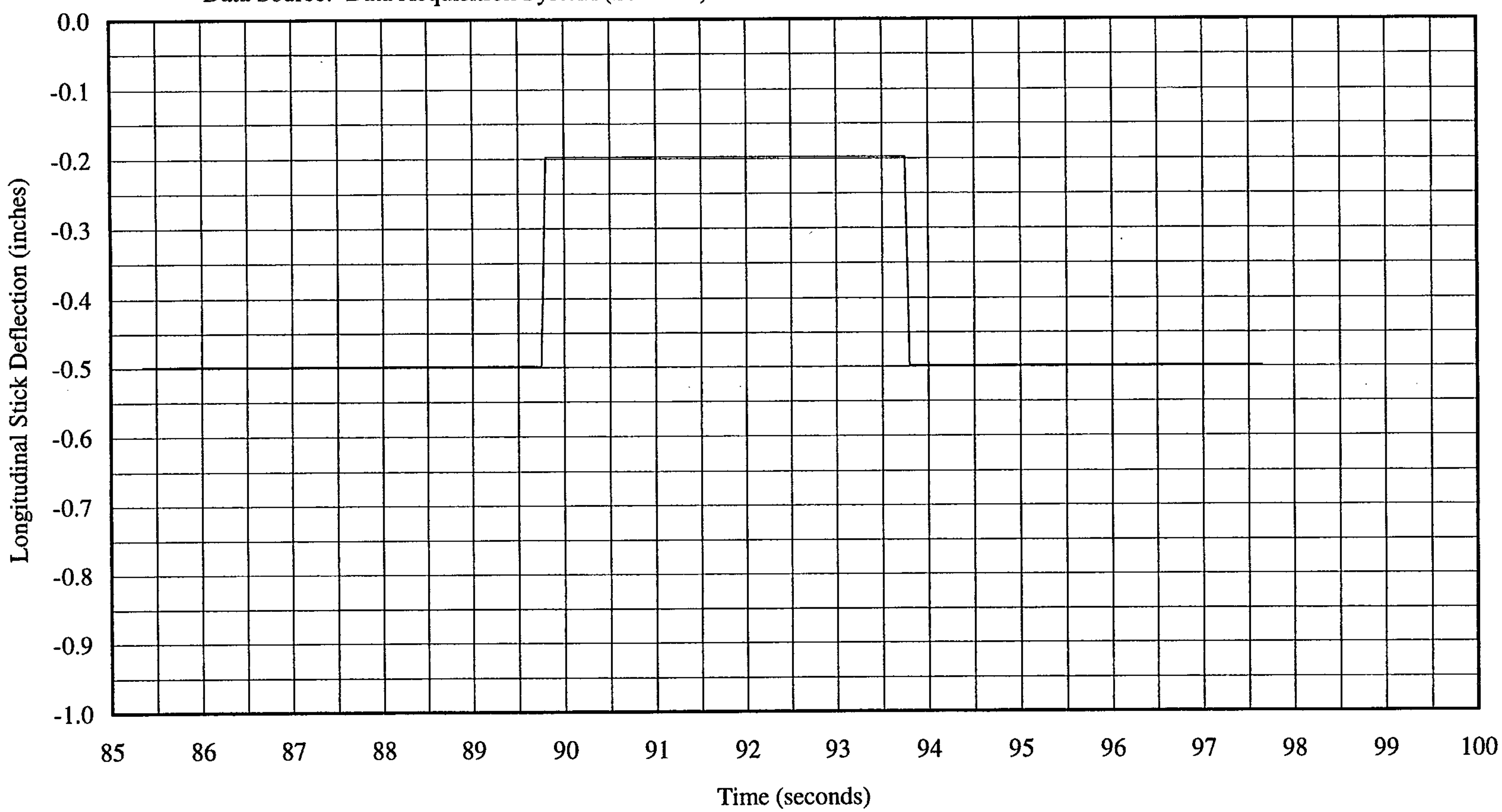

Figure J6 VSS Configuration A Pitch Input Dropback

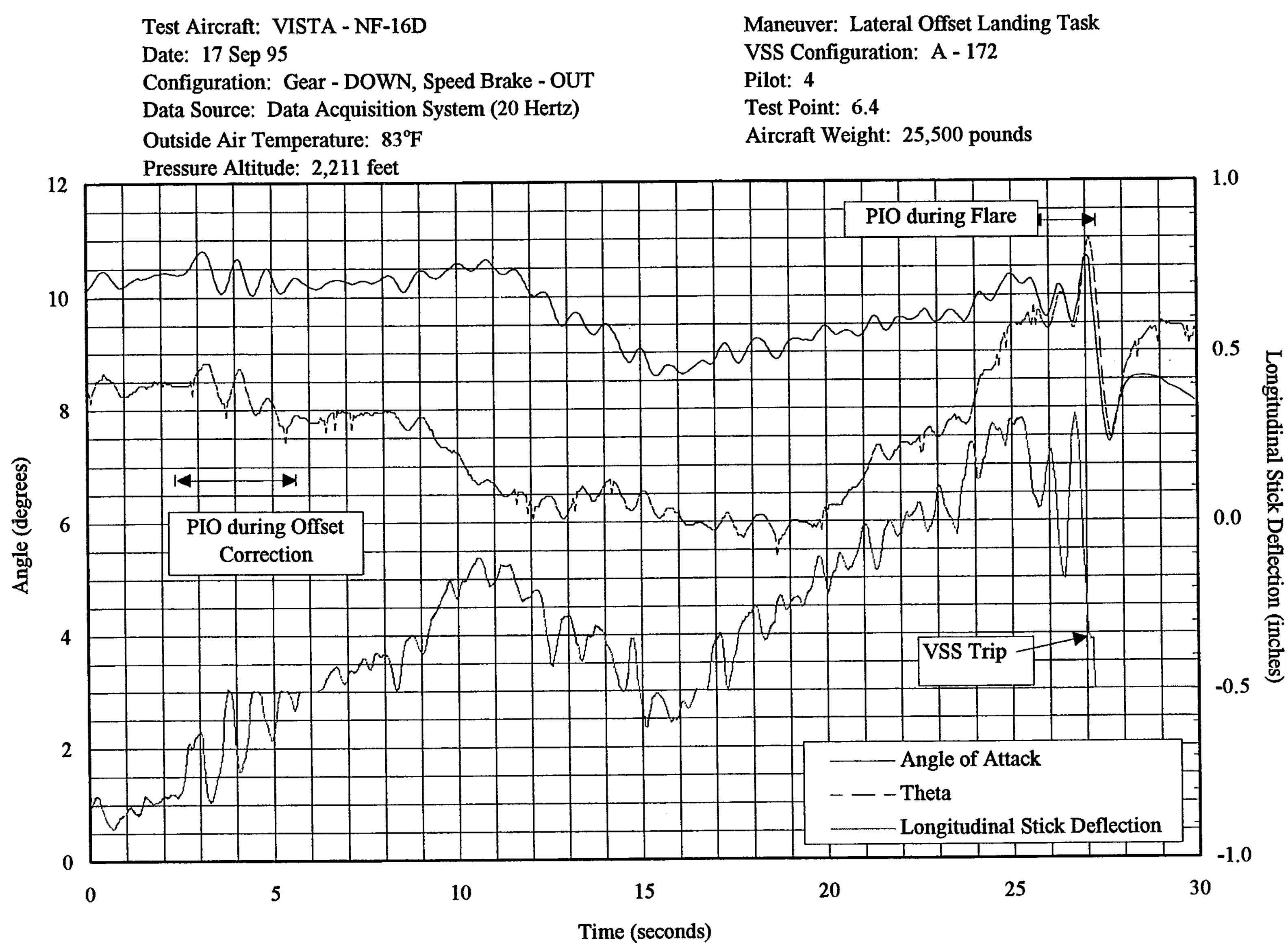

Figure J7 VSS Configuration A Time History of Theta and Longitudinal Stick Deflection

Test Aircraft: VISTA - NF-16D
Date: 17 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 83°F
Pressure Altitude: 2,211 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: A - 172
Pilot: 4
Test Point: 6.4
Aircraft Weight: 25,500 pounds

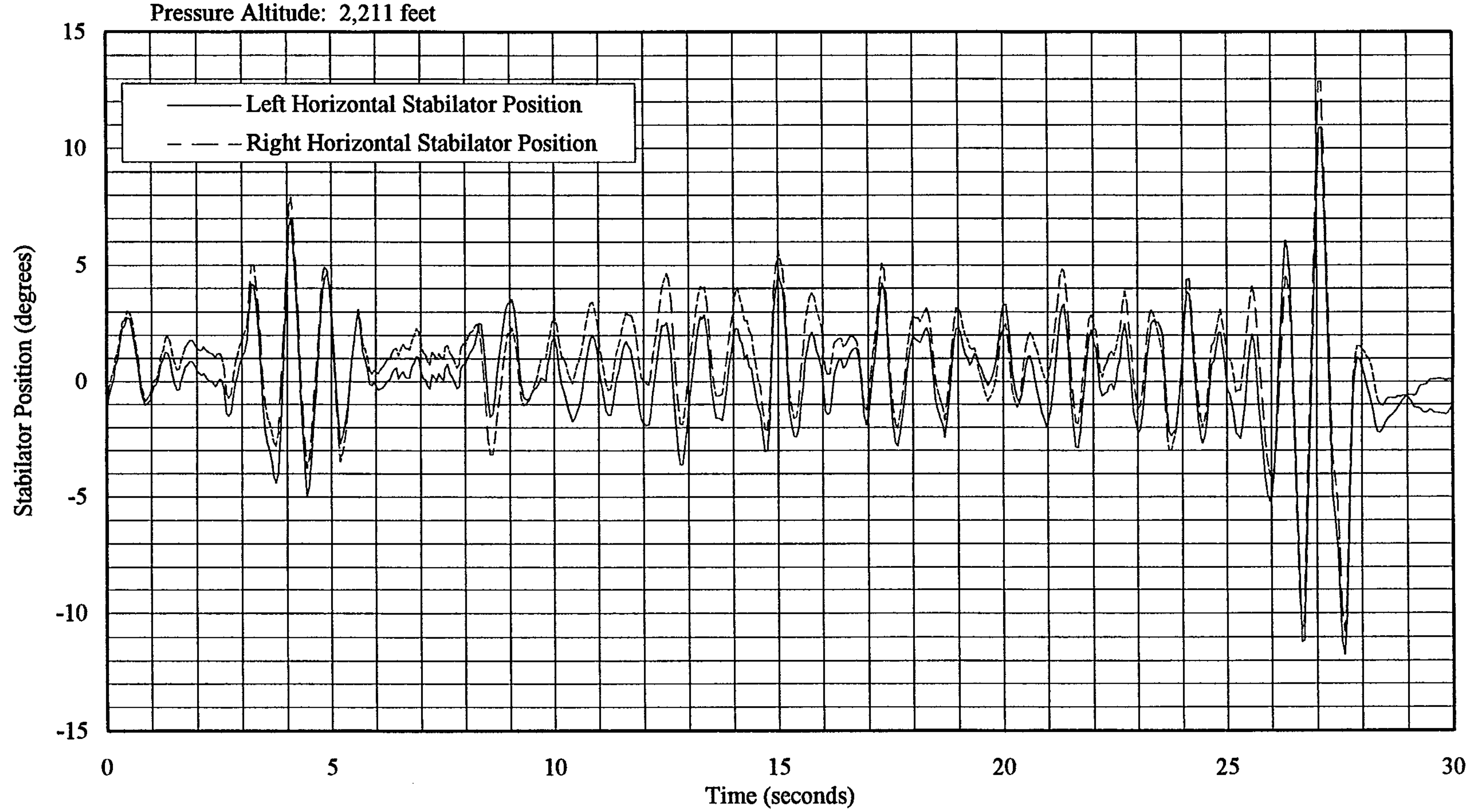

Figure J8 VSS Configuration A Time History of Stabilator Movement

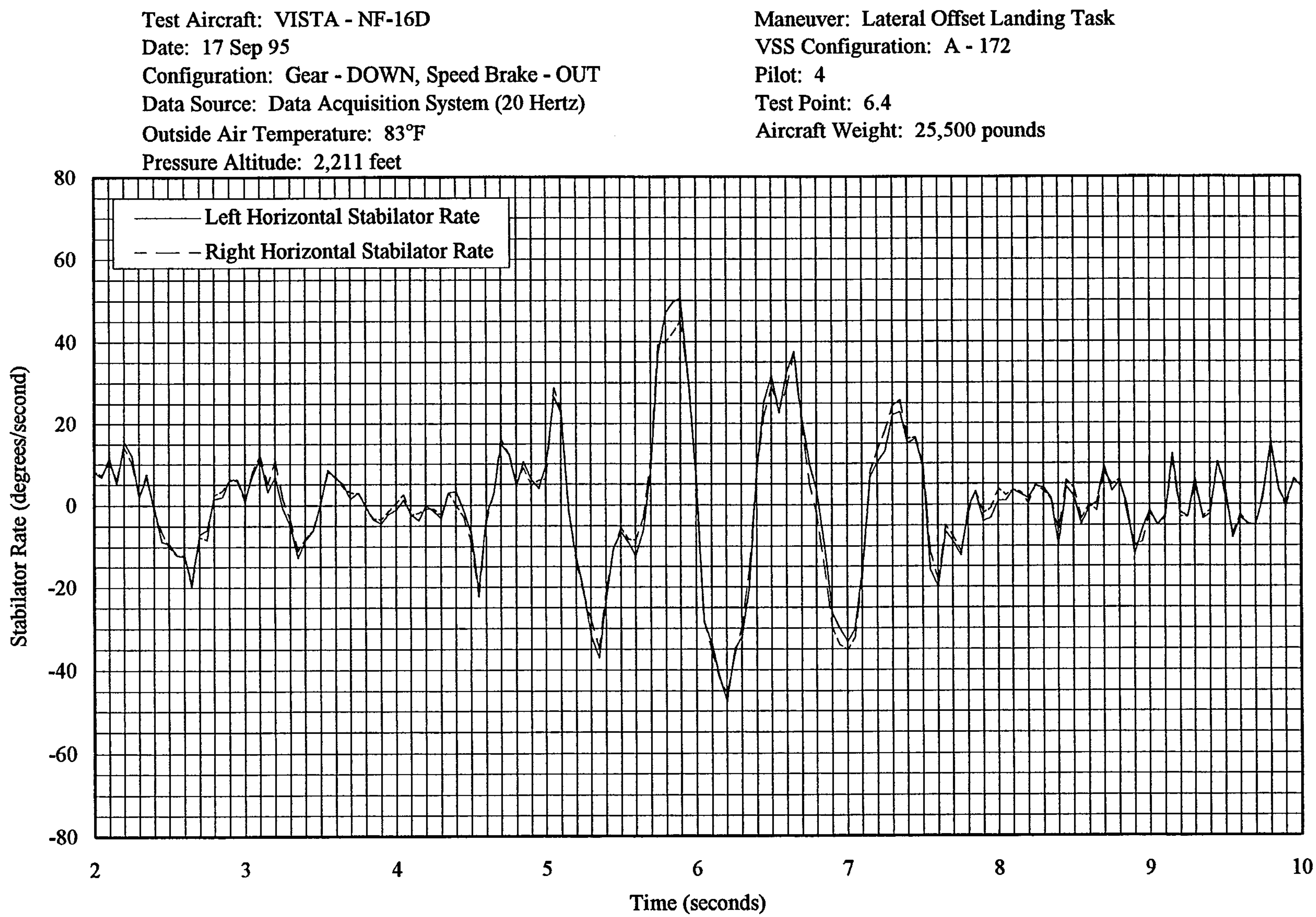

Figure J9 VSS Configuration A Time History of Stabilator Rate (Plot 1)

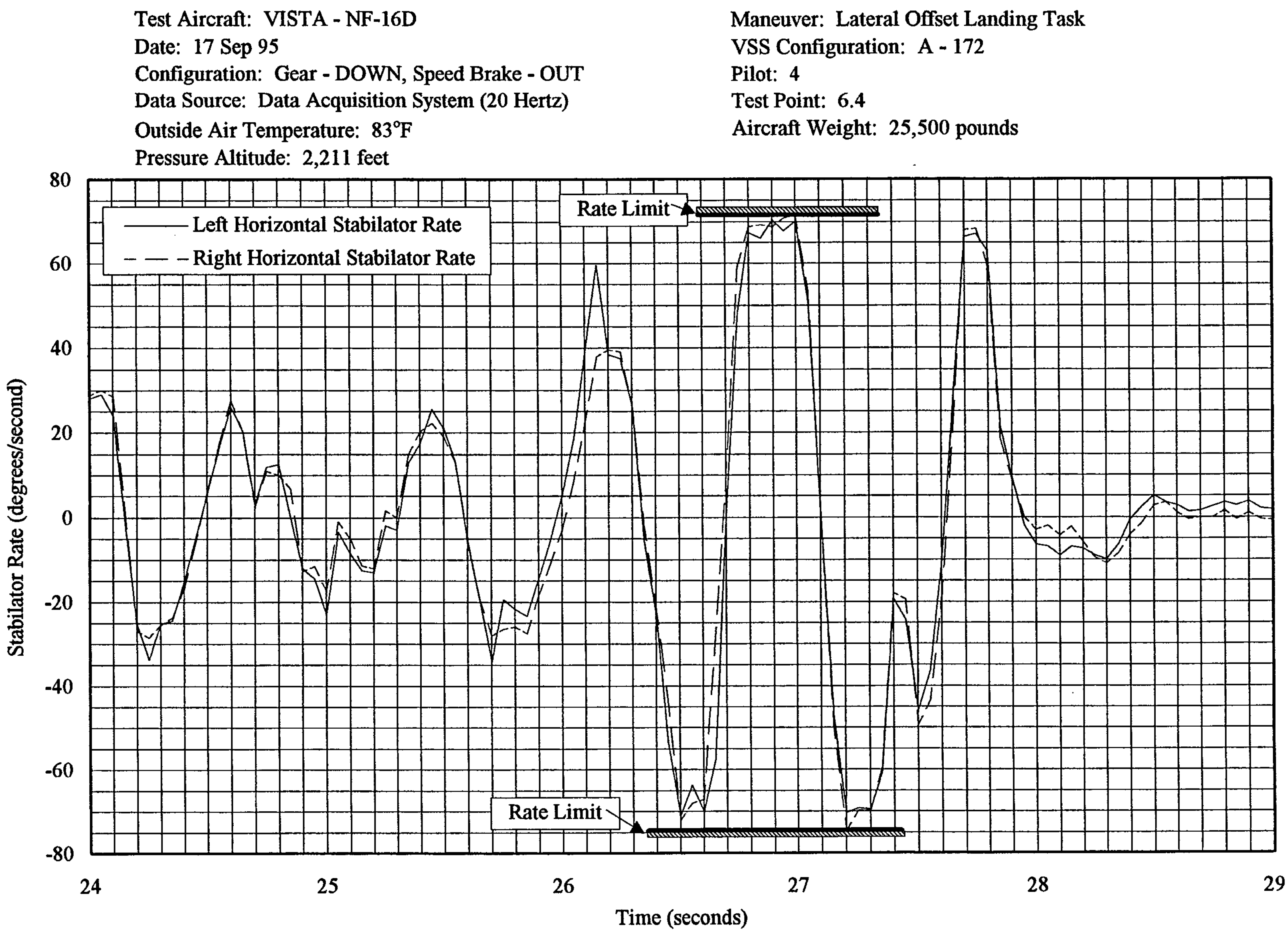

Figure J10 VSS Configuration A Time History of Stabilator Rate (Plot 2)

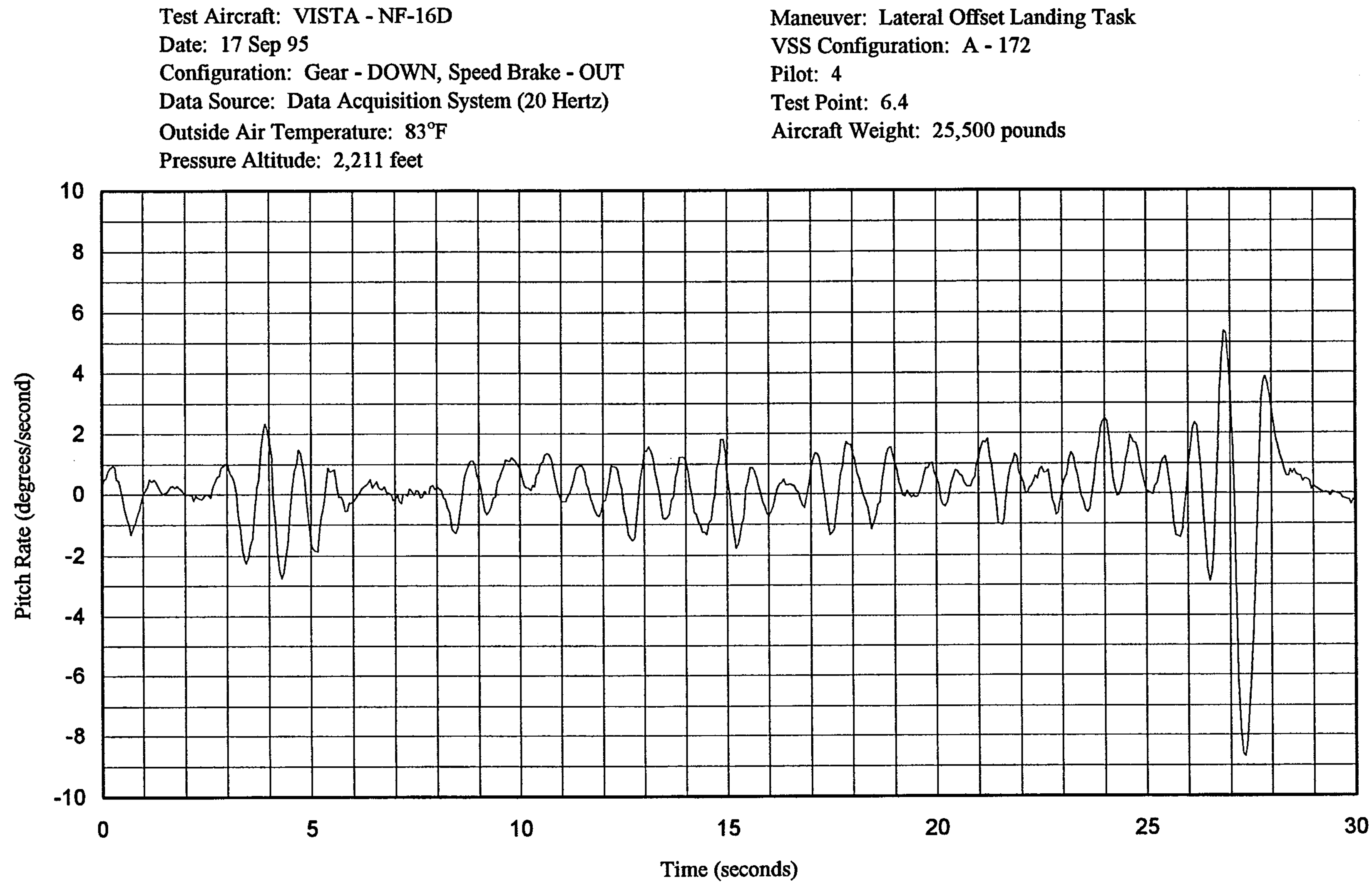

Figure J11 VSS Configuration A Time History of Pitch Rate

Test Aircraft: VISTA - NF-16D
Date: 17 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 83°F
Pressure Altitude: 2,211 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: A - 172
Pilot: 4
Test Point: 6.4
Aircraft Weight: 25,500 pounds

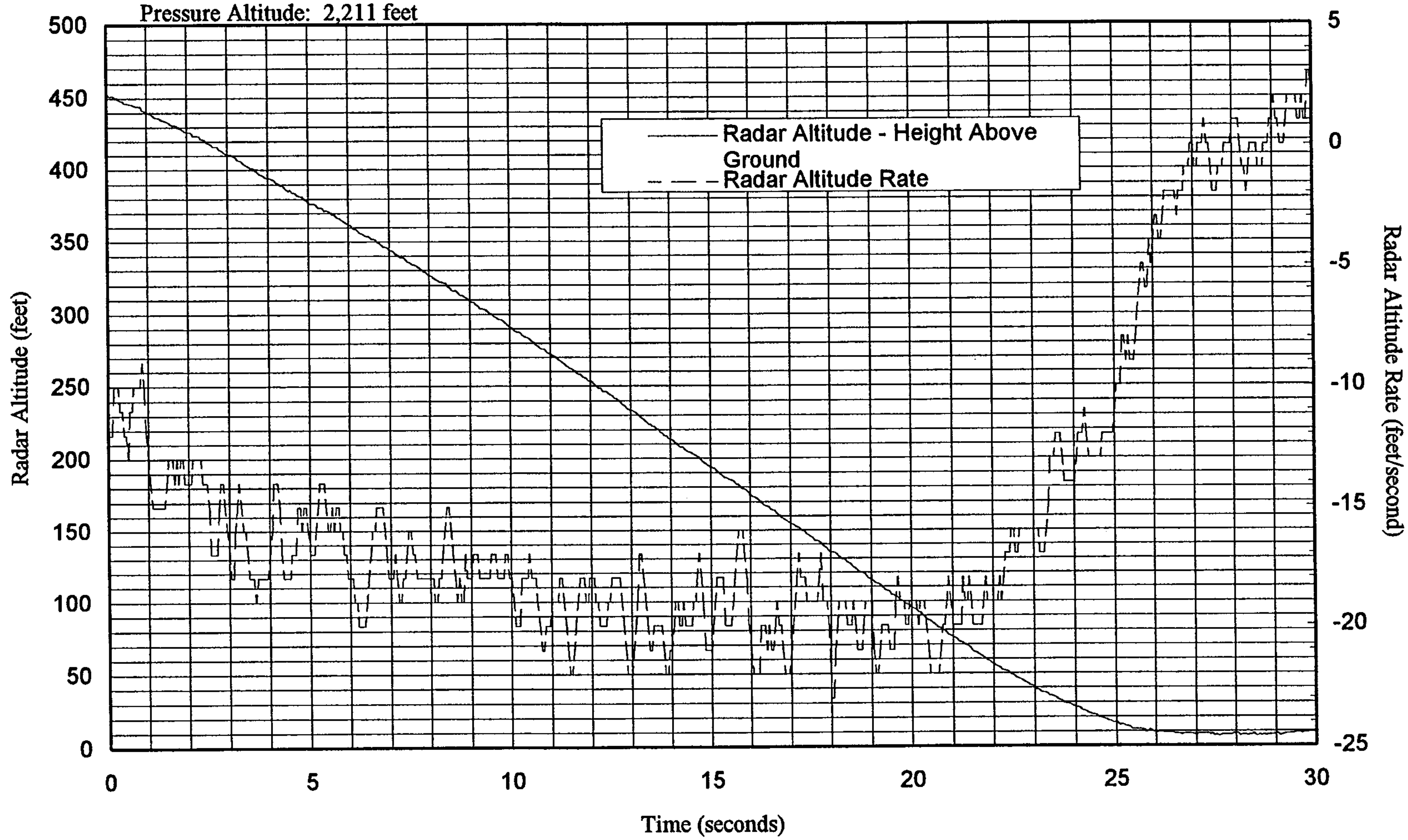

Figure J12 VSS Configuration A Time History of Altitude and Descent Rate

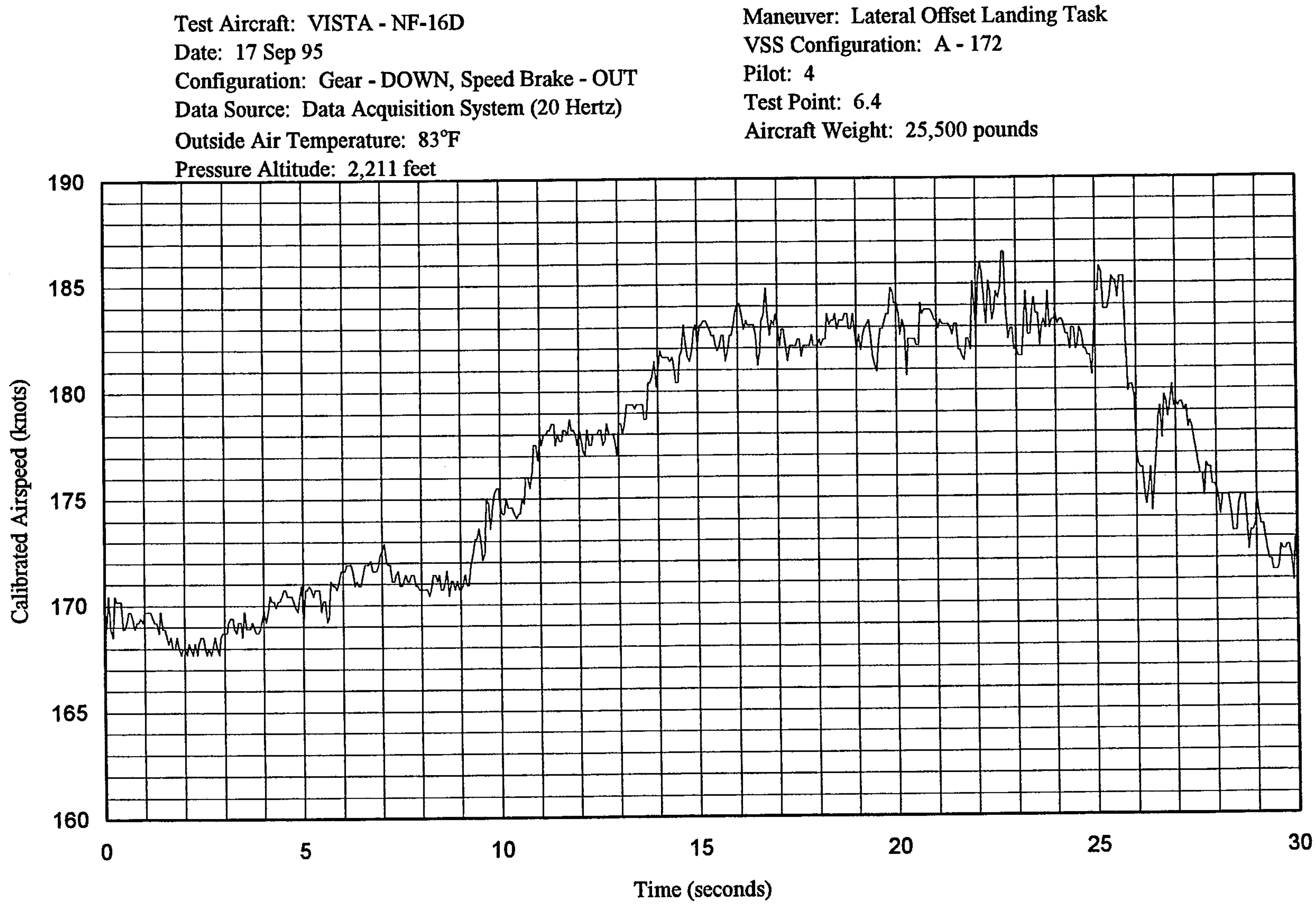

Figure J13 VSS Configuration A Time History of Calibrated Airspeed

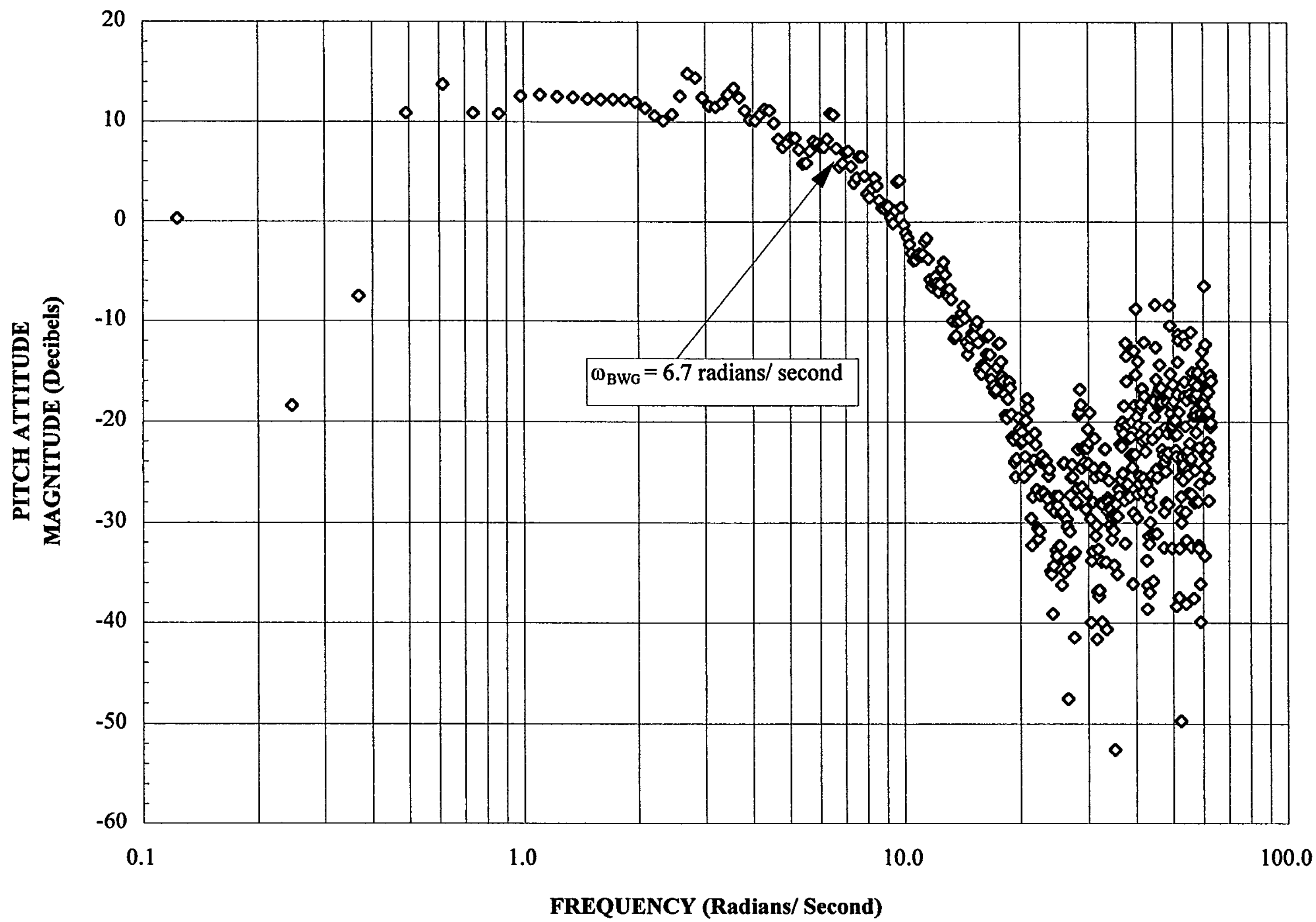

Figure J14 VSS Configuration C2 Magnitude Bode Plot

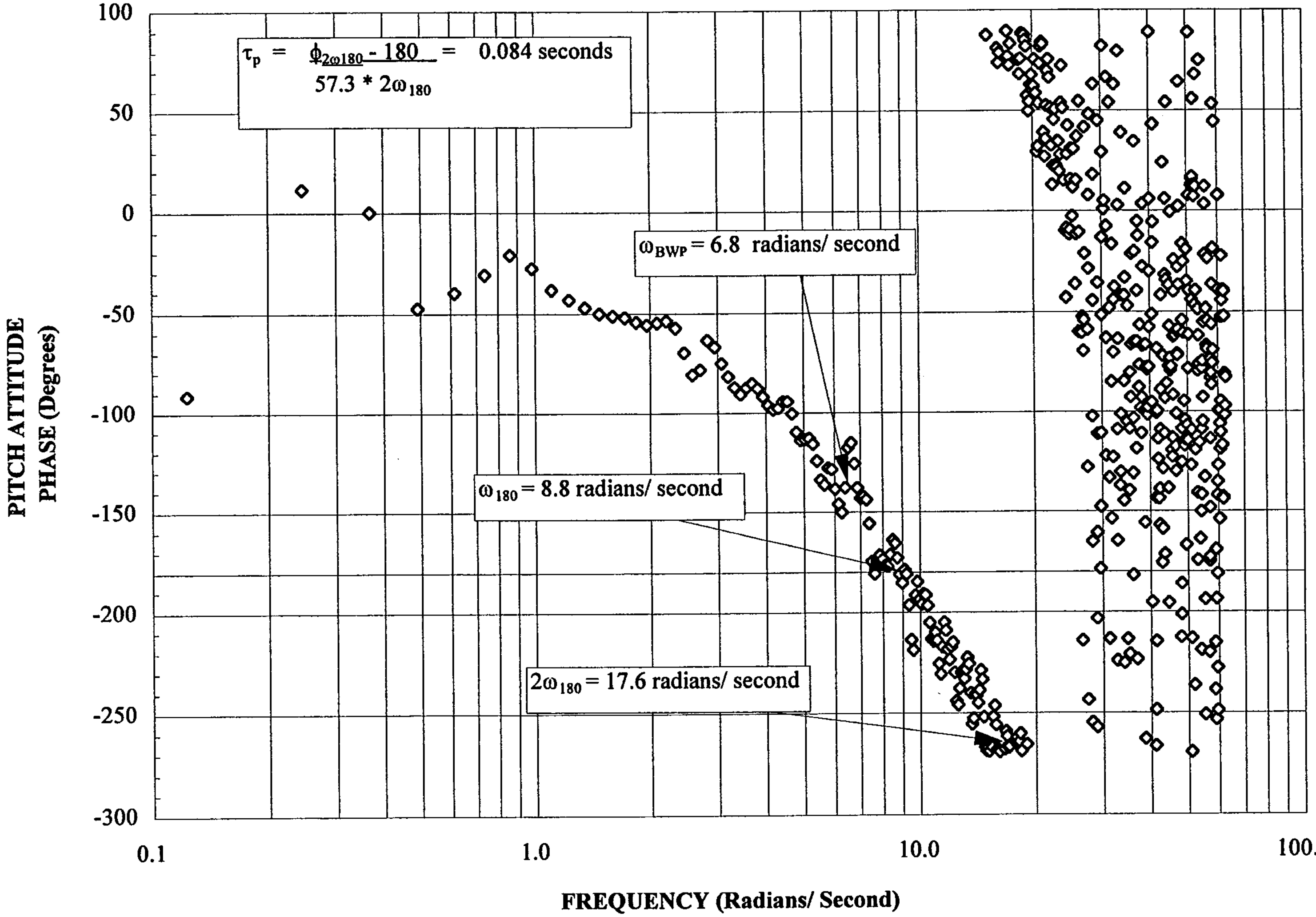

Figure J15 VSS Configuration C2 Phase Bode Plot

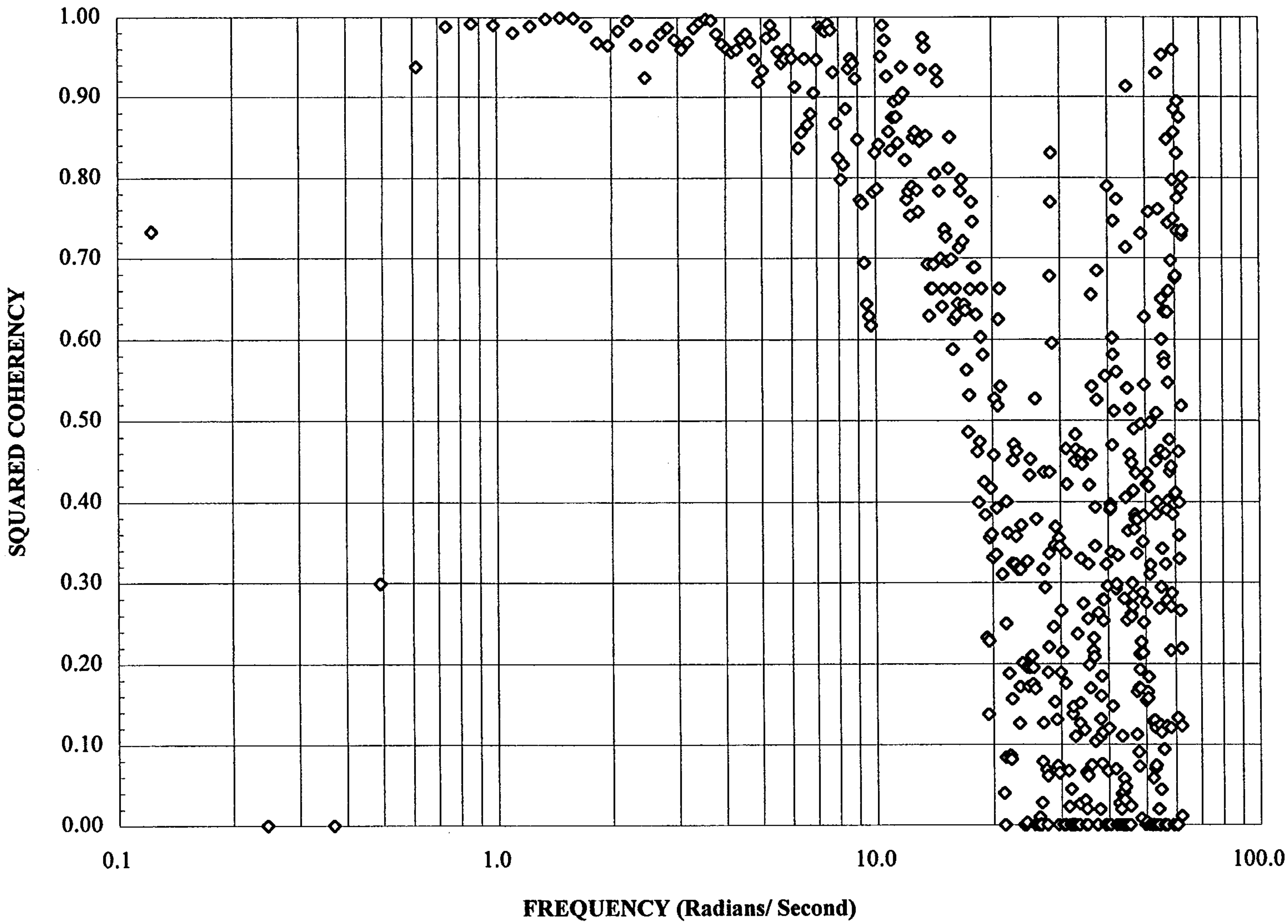

Figure J16 VSS Configuration C2 Bode Squared Coherency Plot

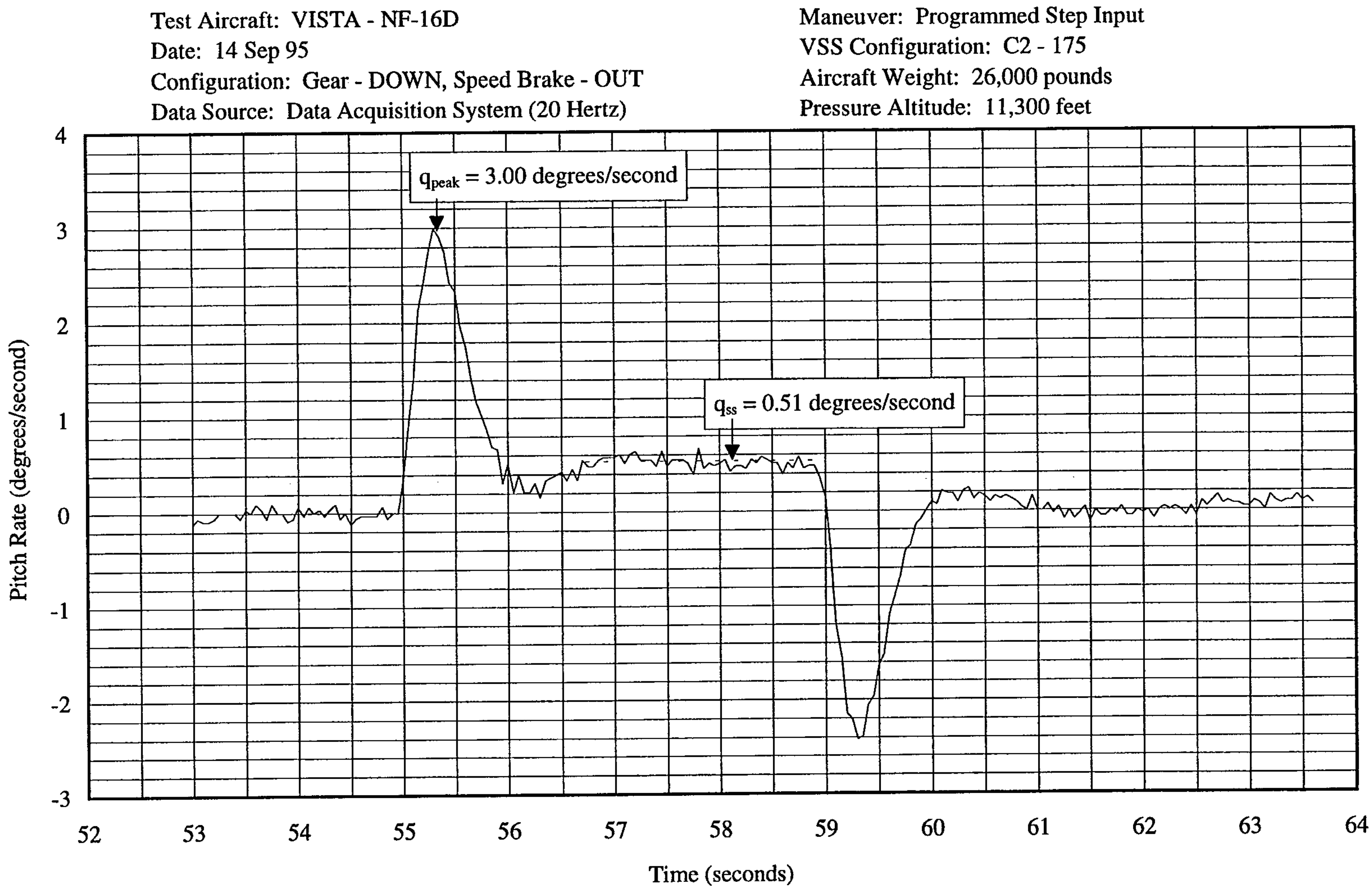

Figure J17 VSS Configuration C2 Pitch Rate Dropback

Test Aircraft: VISTA - NF-16D
Date: 14 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)

Maneuver: Programmed Step Input
VSS Configuration: C2 - 175
Aircraft Weight: 26,000 pounds
Pressure Altitude: 11,300 feet

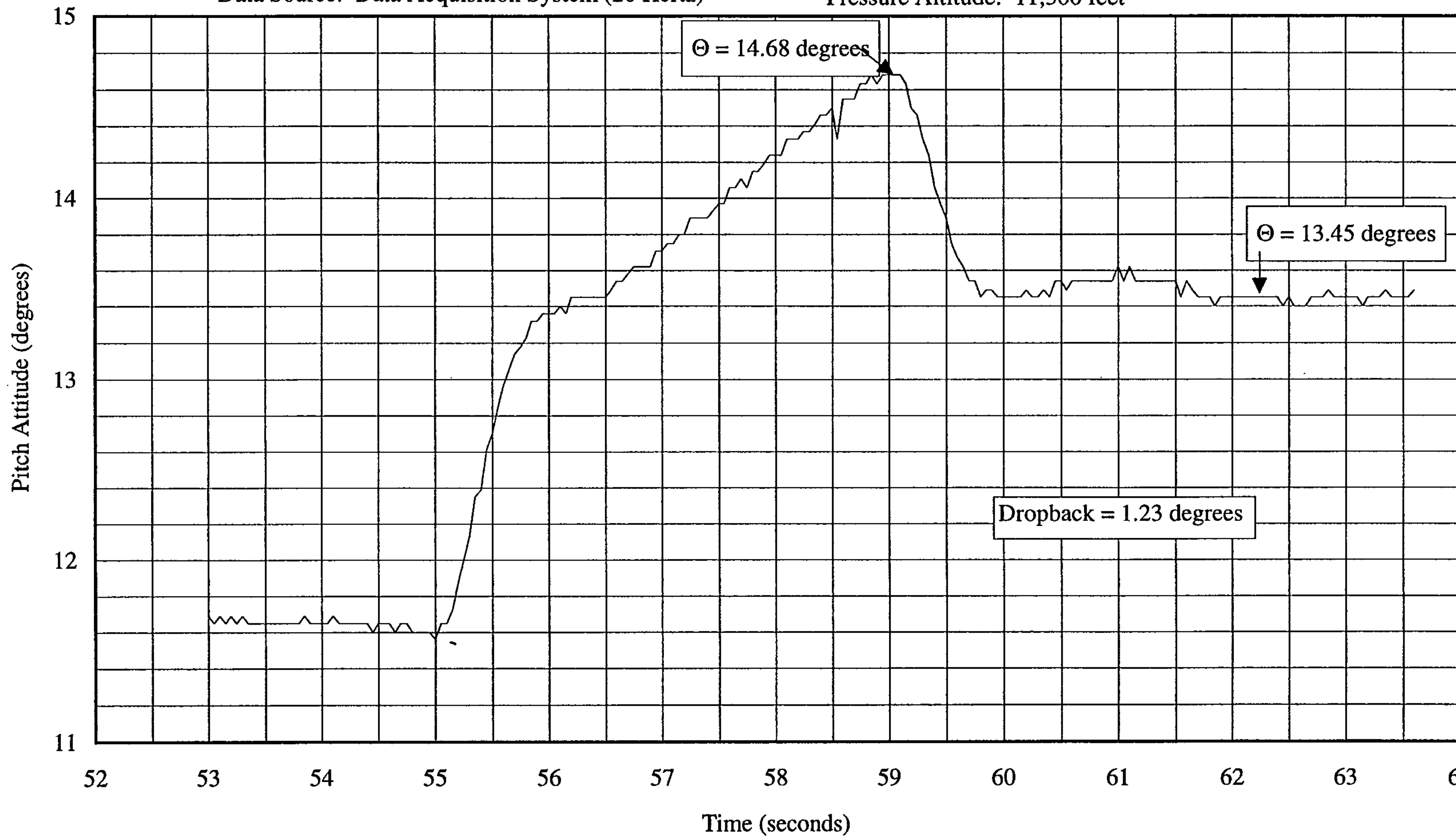

Figure J18 VSS Configuration C2 Pitch Angle Dropback

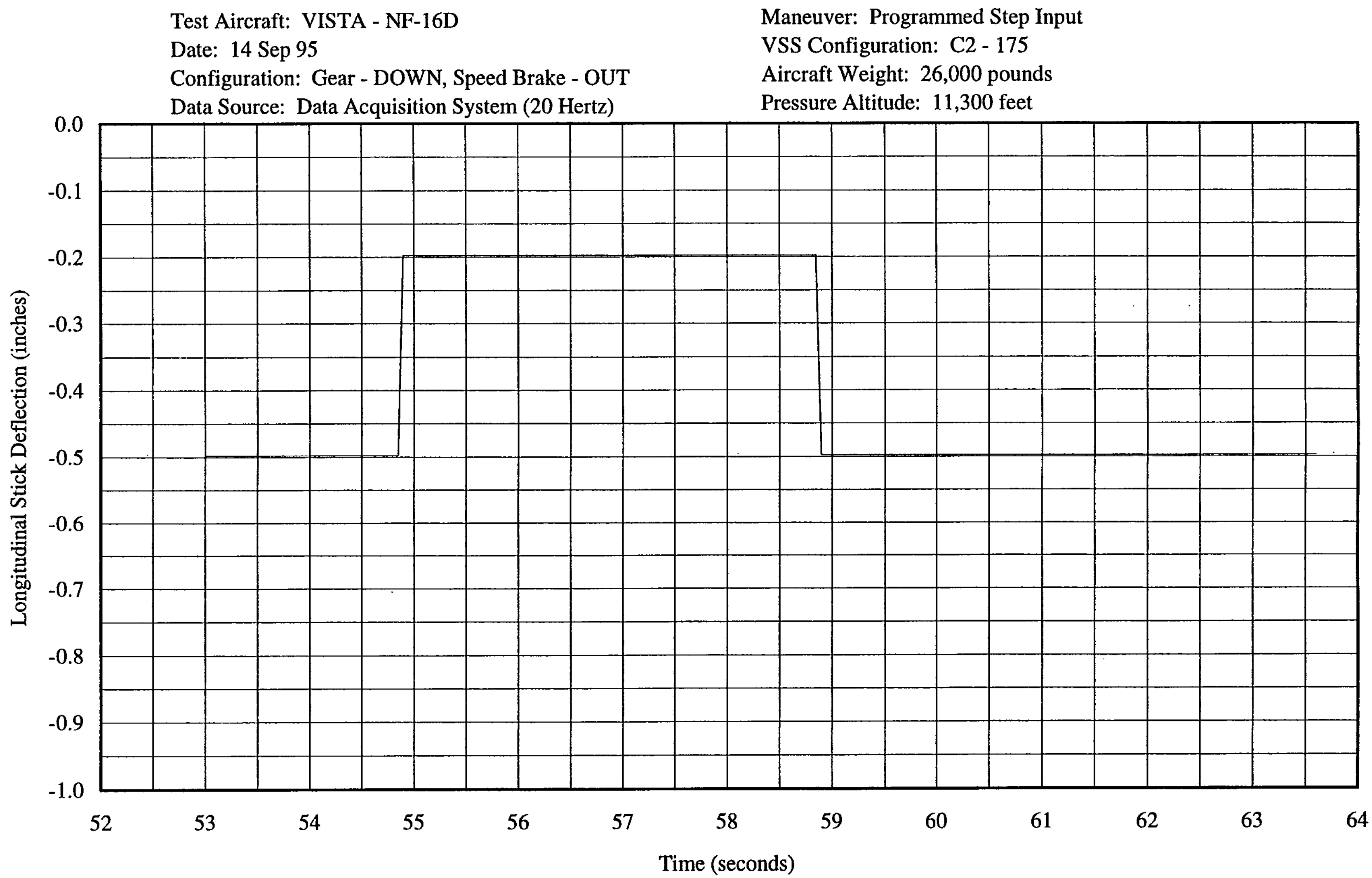

Figure J19 VSS Configuration C2 Pitch Input Dropback

Test Aircraft: VISTA - NF-16D
Date: 16 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 98°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: C2 - 175
Pilot: 3
Test Point: 5.4
Aircraft Weight: 25,300 pounds

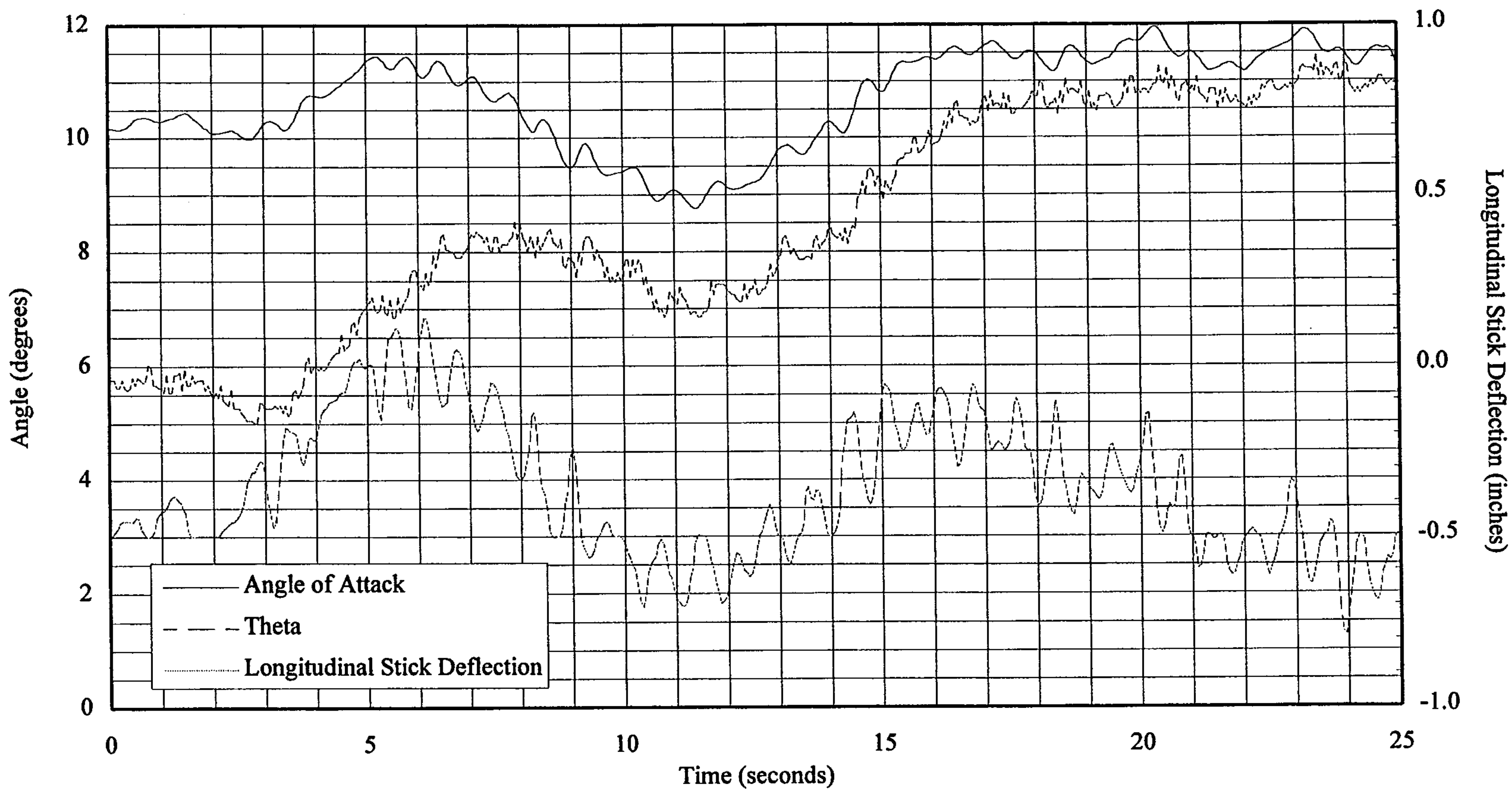

Figure J20 VSS Configuration C2 Time History of Theta and Longitudinal Stick Deflection

Test Aircraft: VISTA - NF-16D
Date: 16 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 98°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: C2 - 175
Pilot: 3
Test Point: 5.4
Aircraft Weight: 25,300 pounds

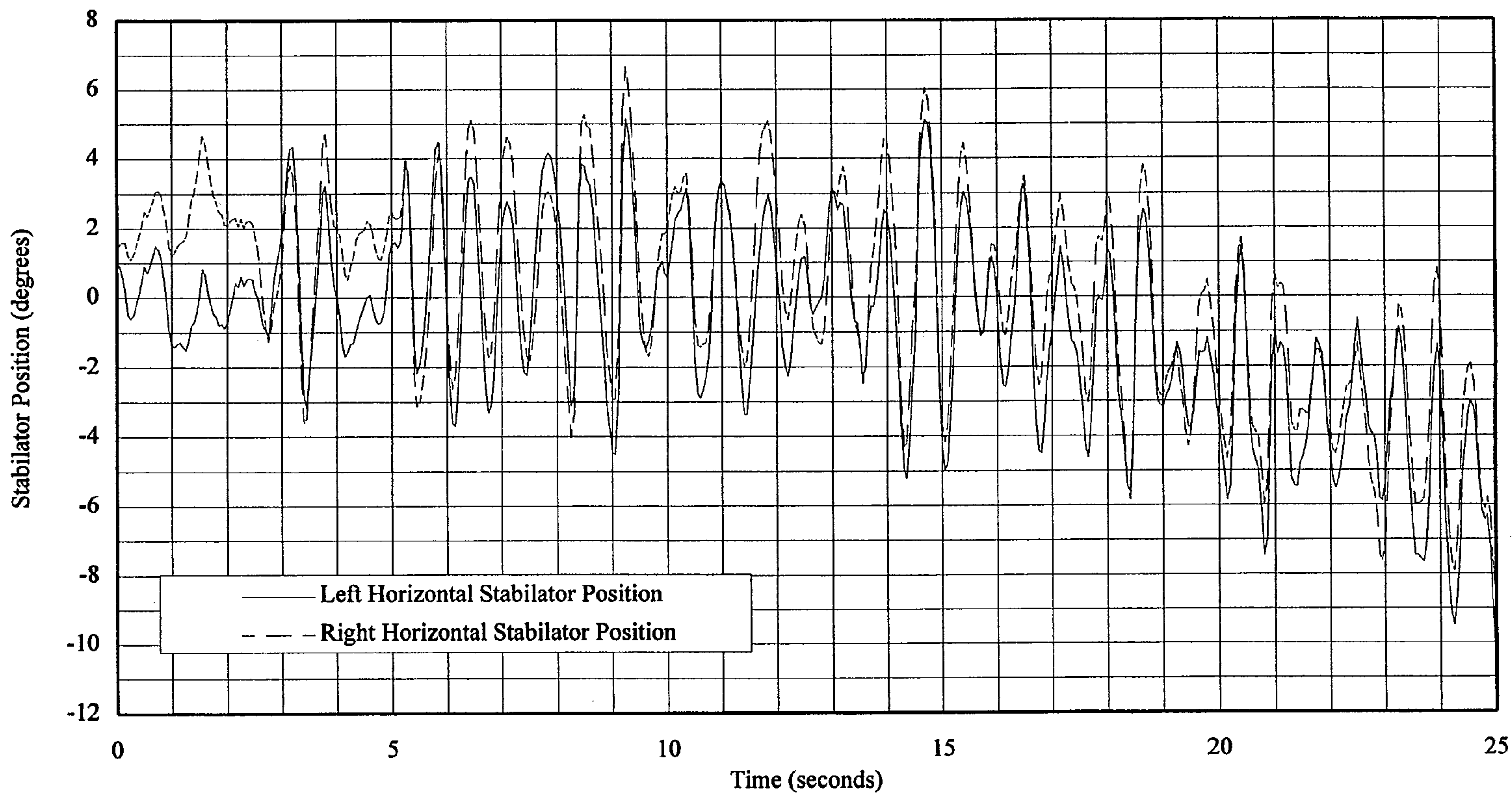

Figure J21 VSS Configuration C2 Time History of Stabilator Movement

Test Aircraft: VISTA - NF-16D
Date: 16 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 98°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: C2 - 175
Pilot: 3
Test Point: 5.4
Aircraft Weight: 25,300 pounds

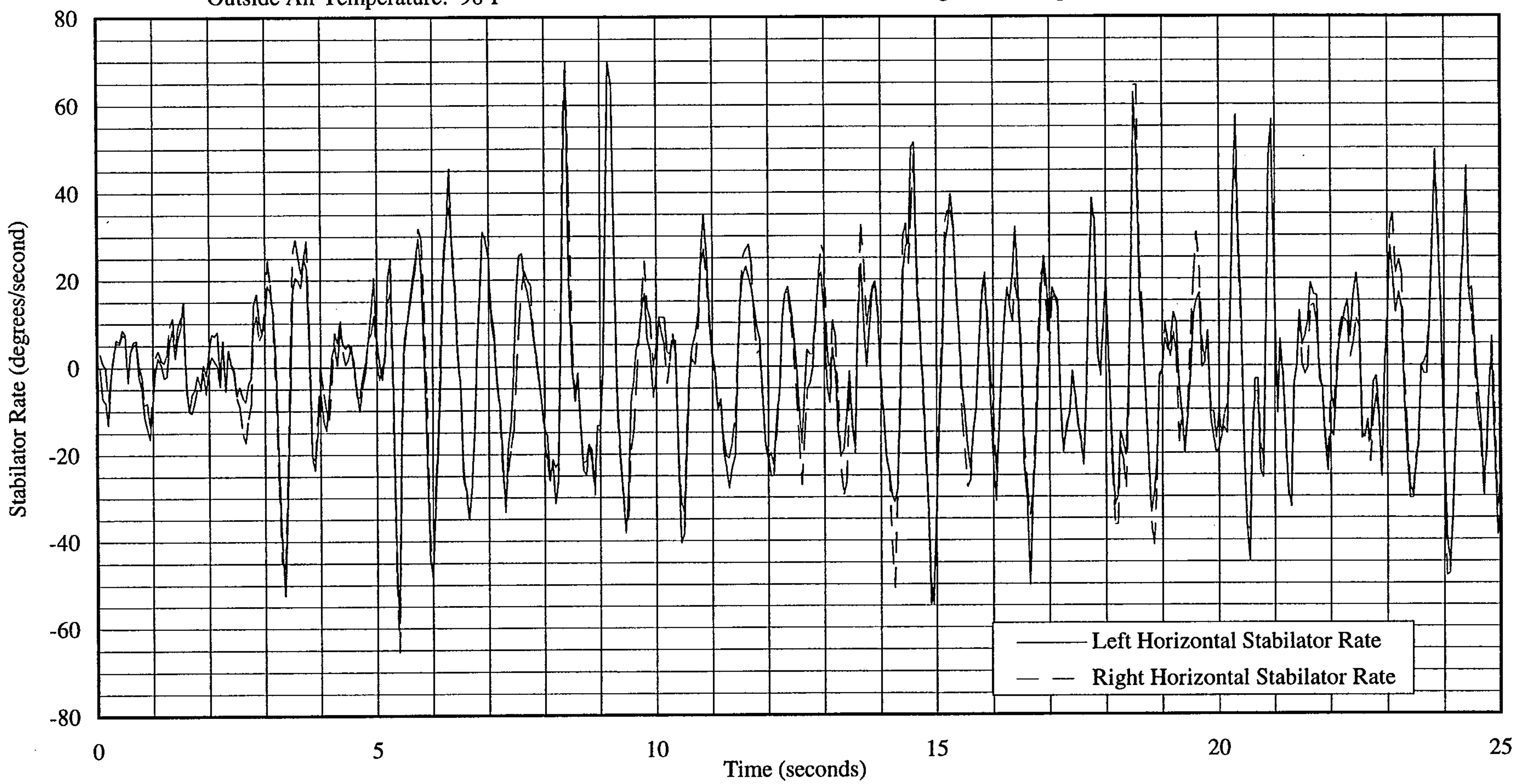

Figure J22 VSS Configuration C2 Time History of Stabilator Rate

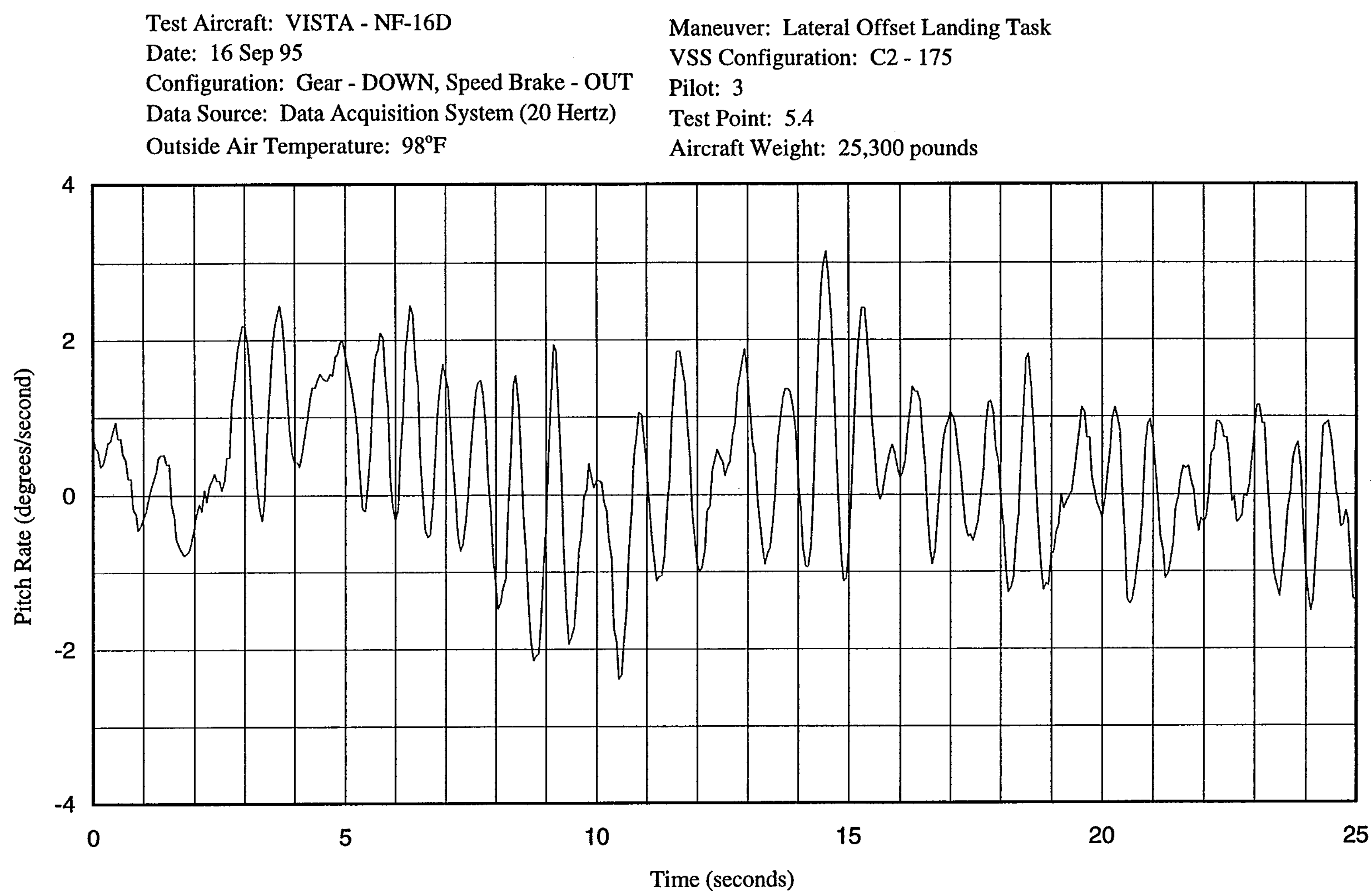

Figure J23 VSS Configuration C2 Time History of Pitch Rate

Test Aircraft: VISTA - NF-16D
Date: 16 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 98°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: C2 - 175
Pilot: 3
Test Point: 5.4
Aircraft Weight: 25,300 pounds

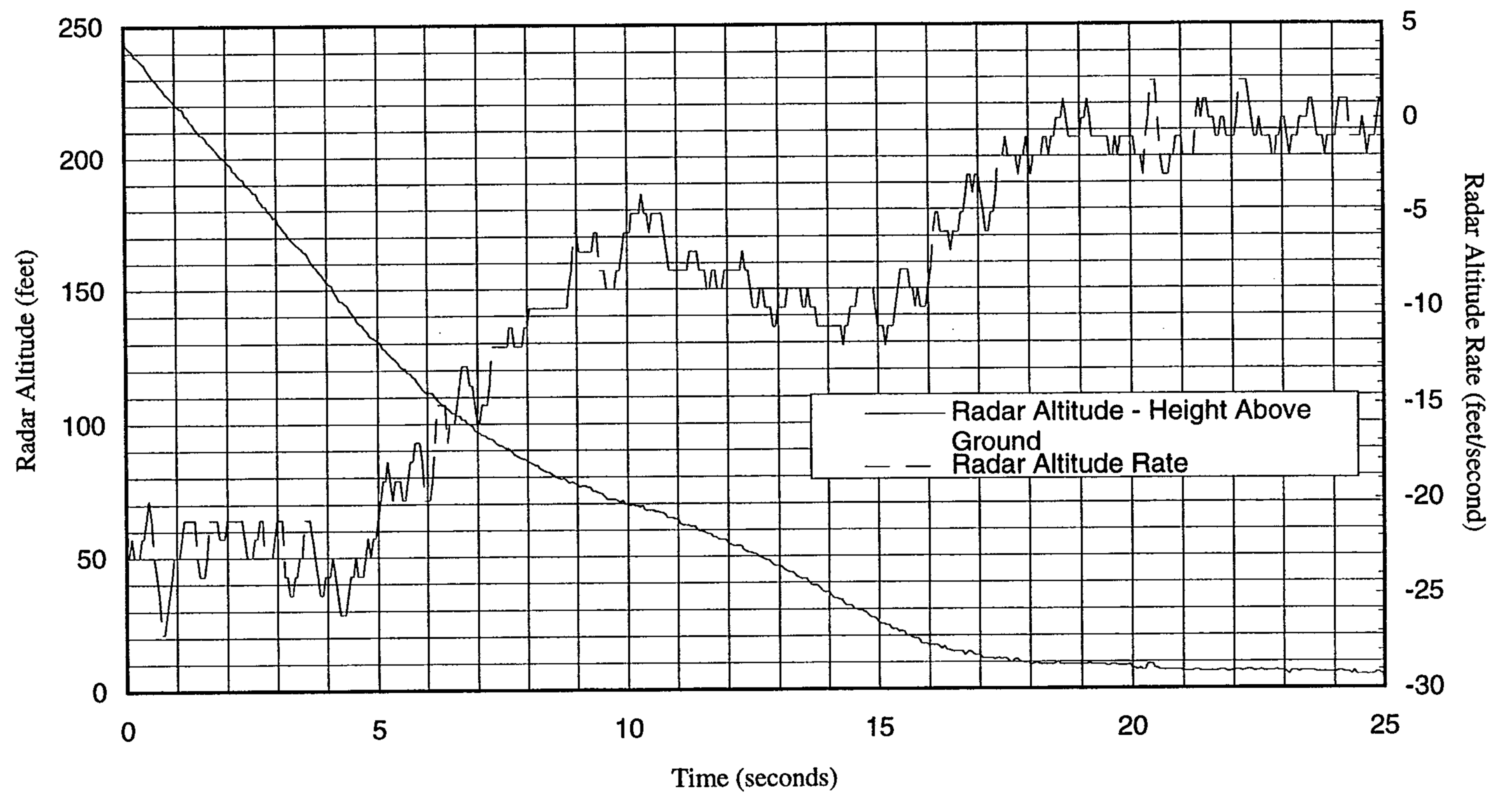

Figure J24 VSS Configuration C2 Time History of Altitude and Descent Rate

Test Aircraft: VISTA - NF-16D
Date: 16 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 98°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: C2 - 175
Pilot: 3
Test Point: 5.4
Aircraft Weight: 25,300 pounds

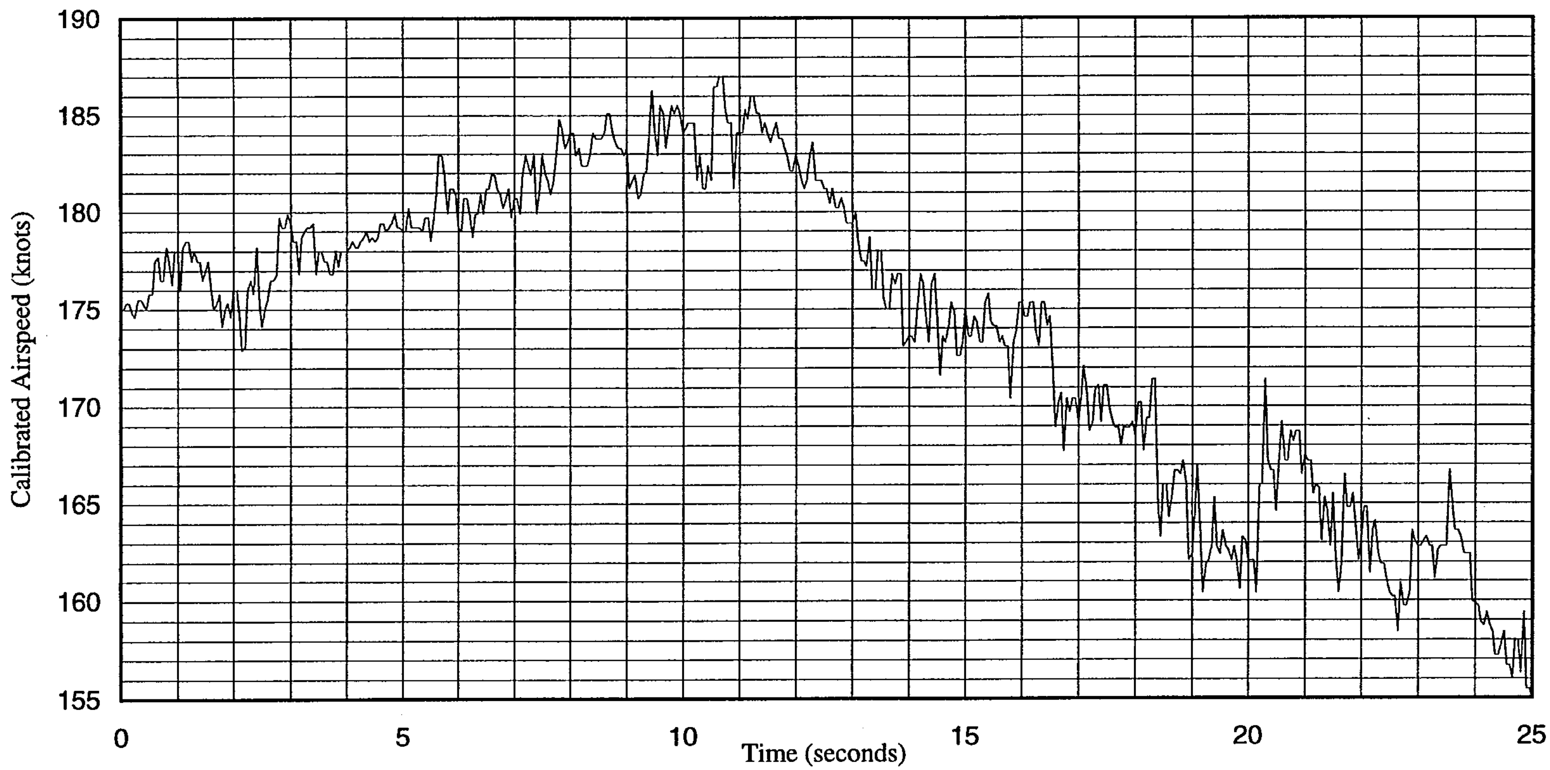

Figure J25 VSS Configuration C2 Time History of Calibrated Airspeed

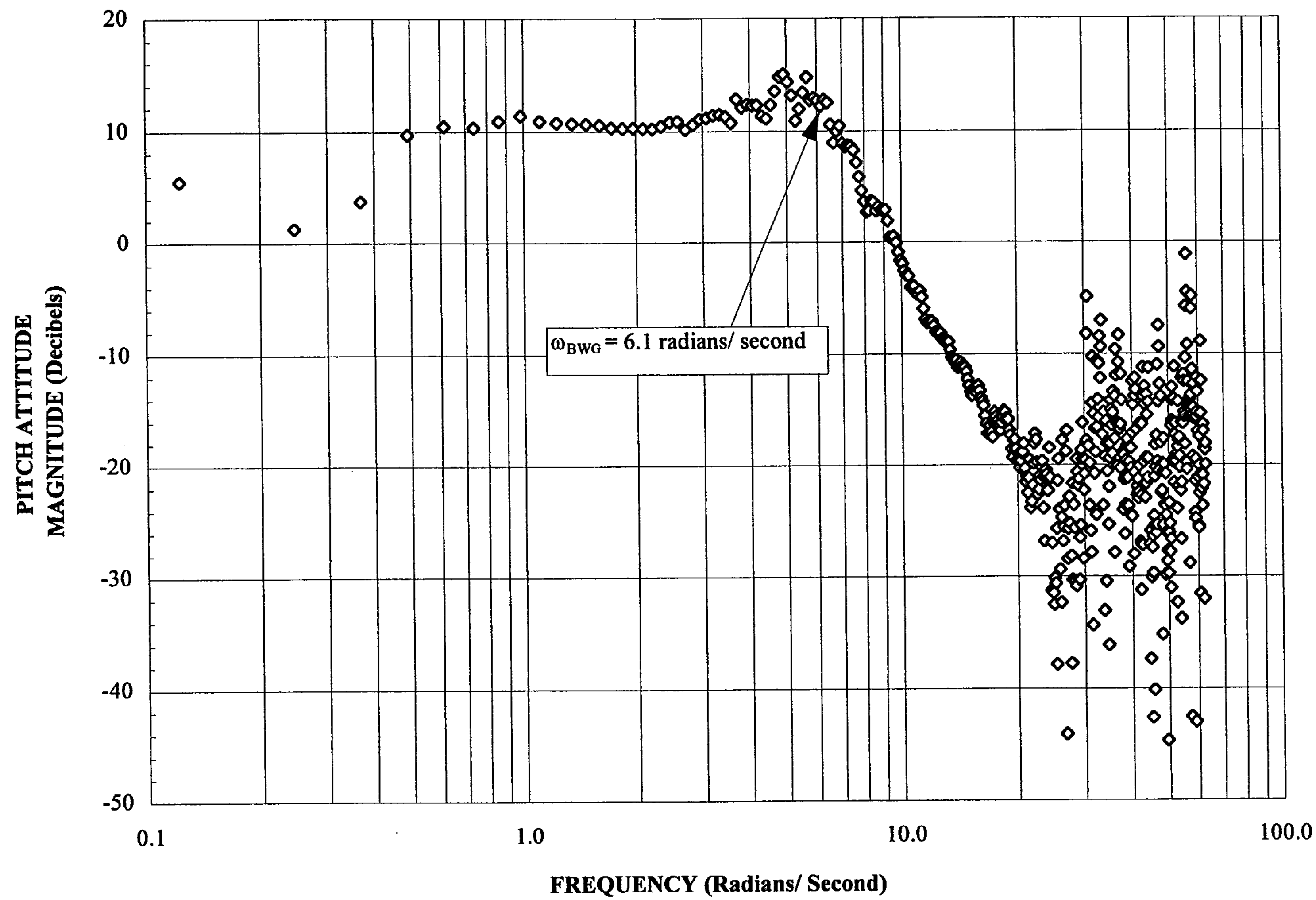

Figure J26 VSS Configuration D Magnitude Bode Plot

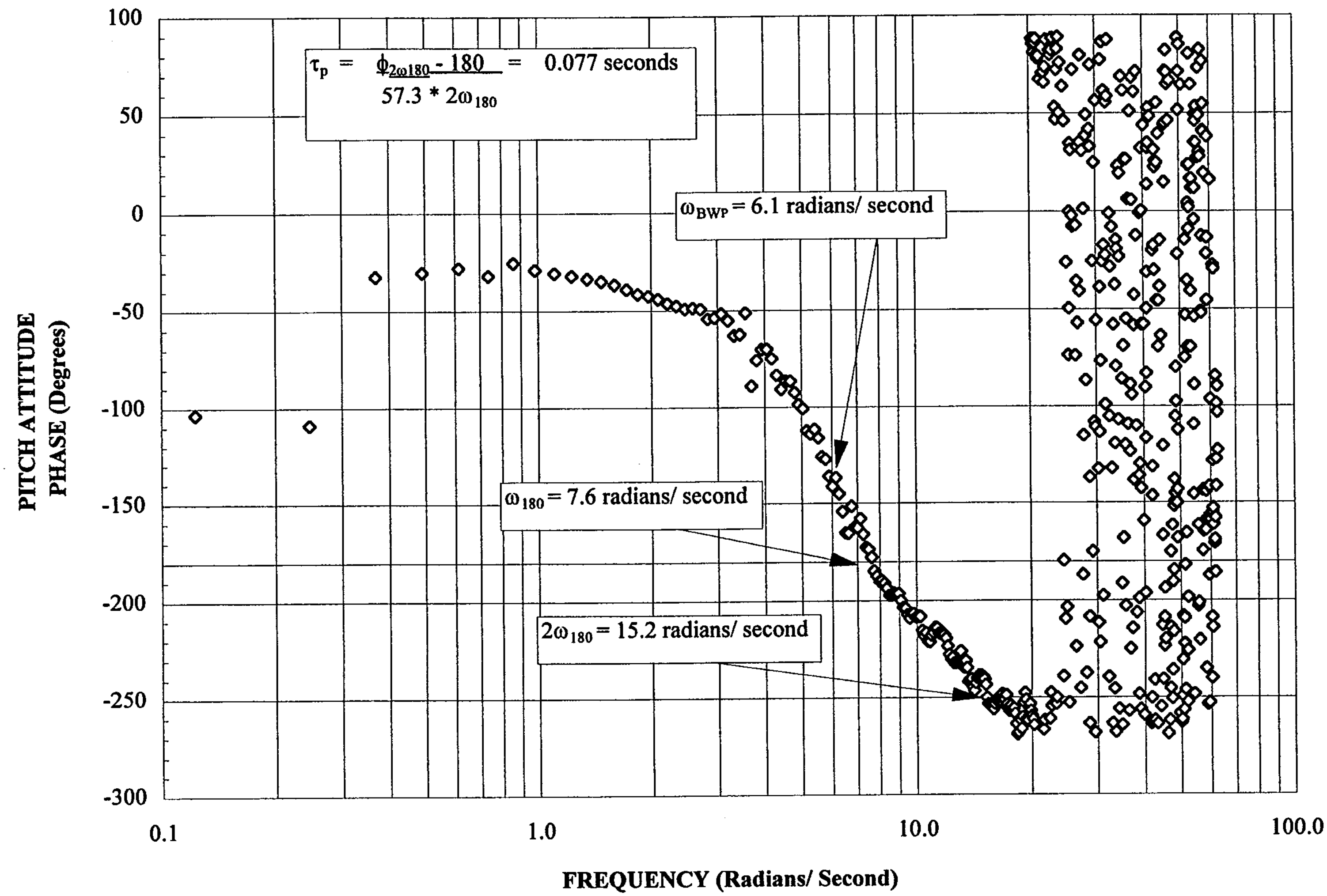

Figure J27 VSS Configuration D Phase Bode Plot

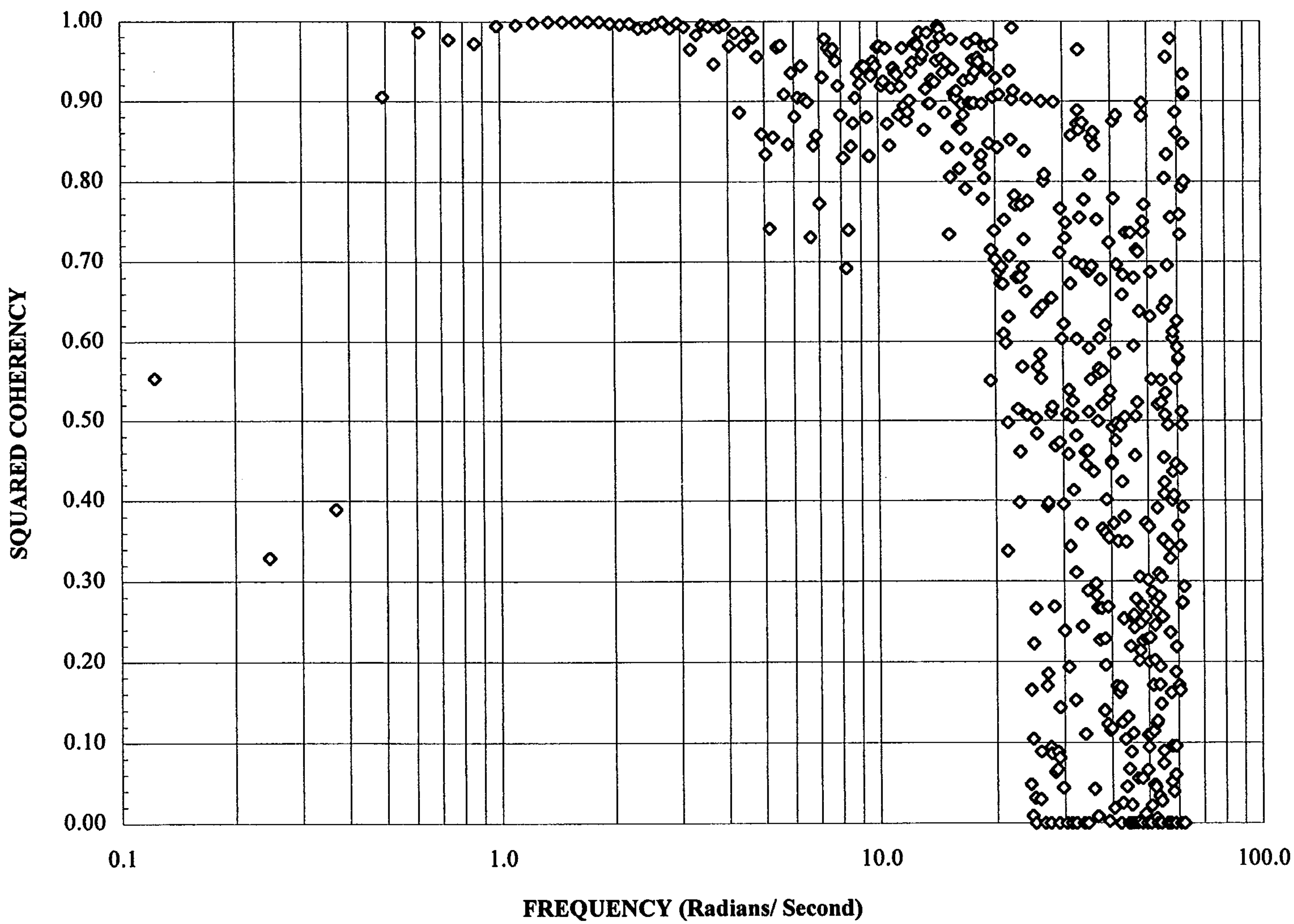

Figure J28 VSS Configuration D Bode Squared Coherency Plot

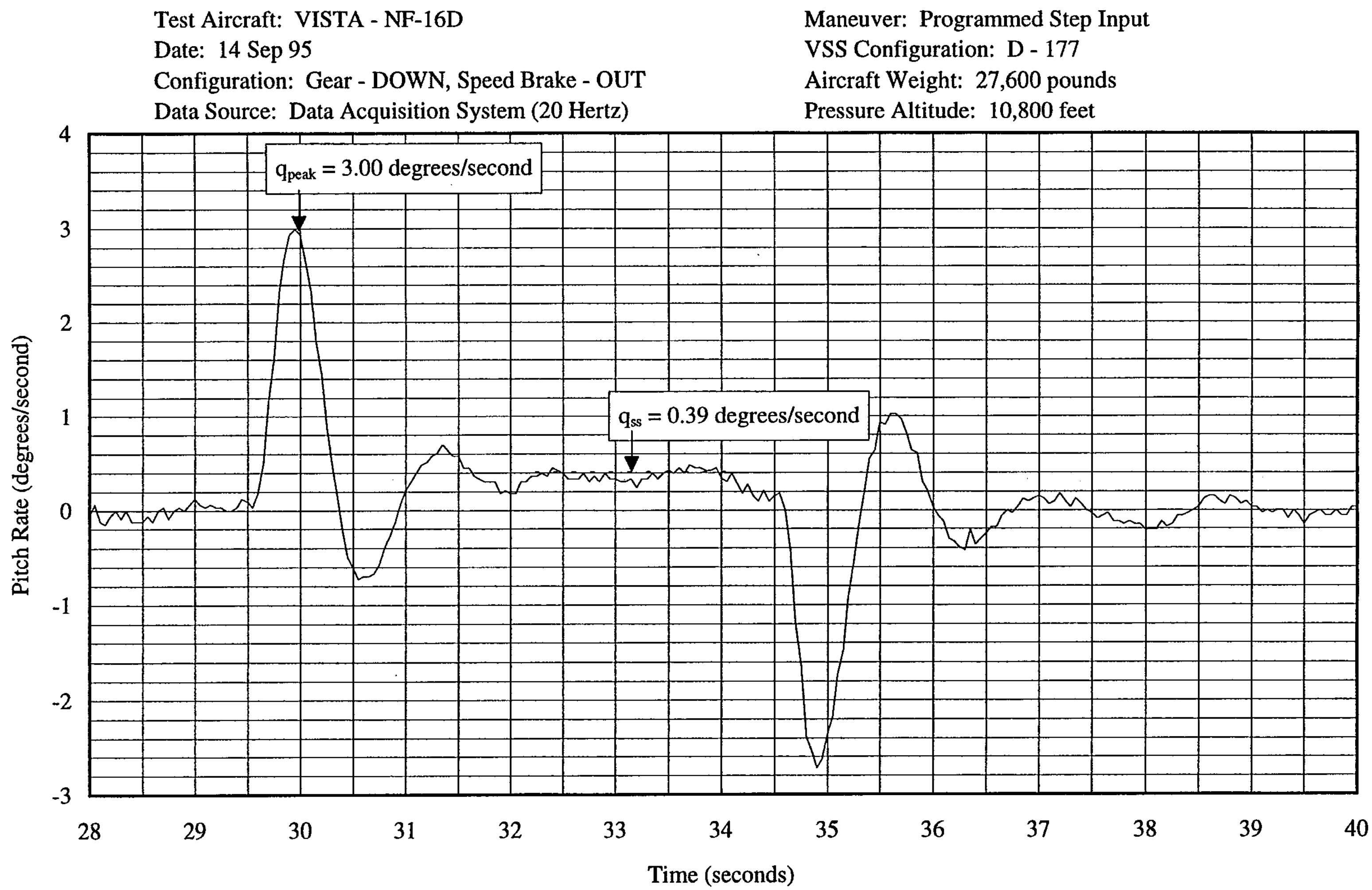

Figure J29 VSS Configuration D Pitch Rate Dropback

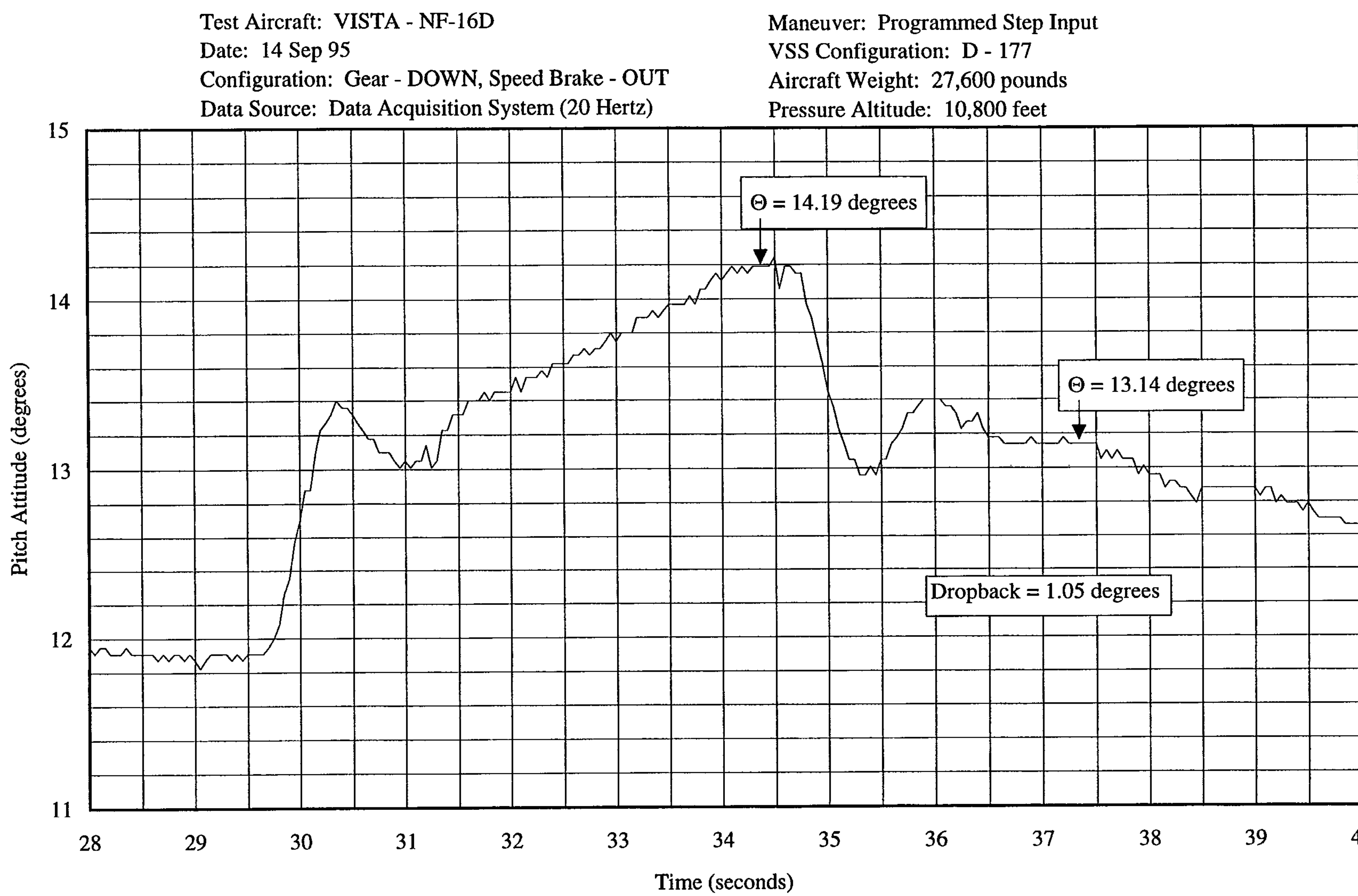

Figure J30 VSS Configuration D Pitch Angle Dropback

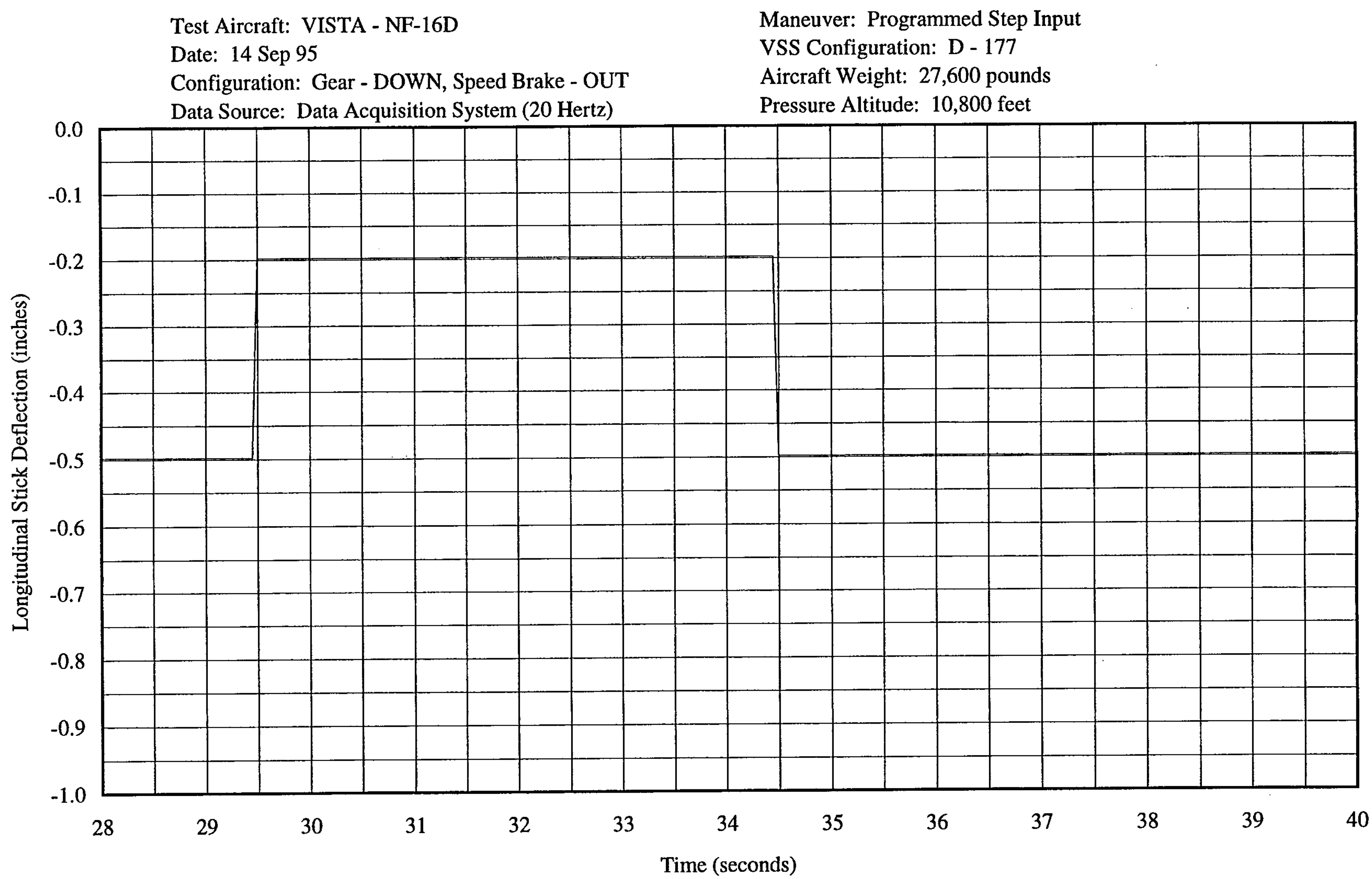

Figure J31 VSS Configuration D Pitch Input Dropback

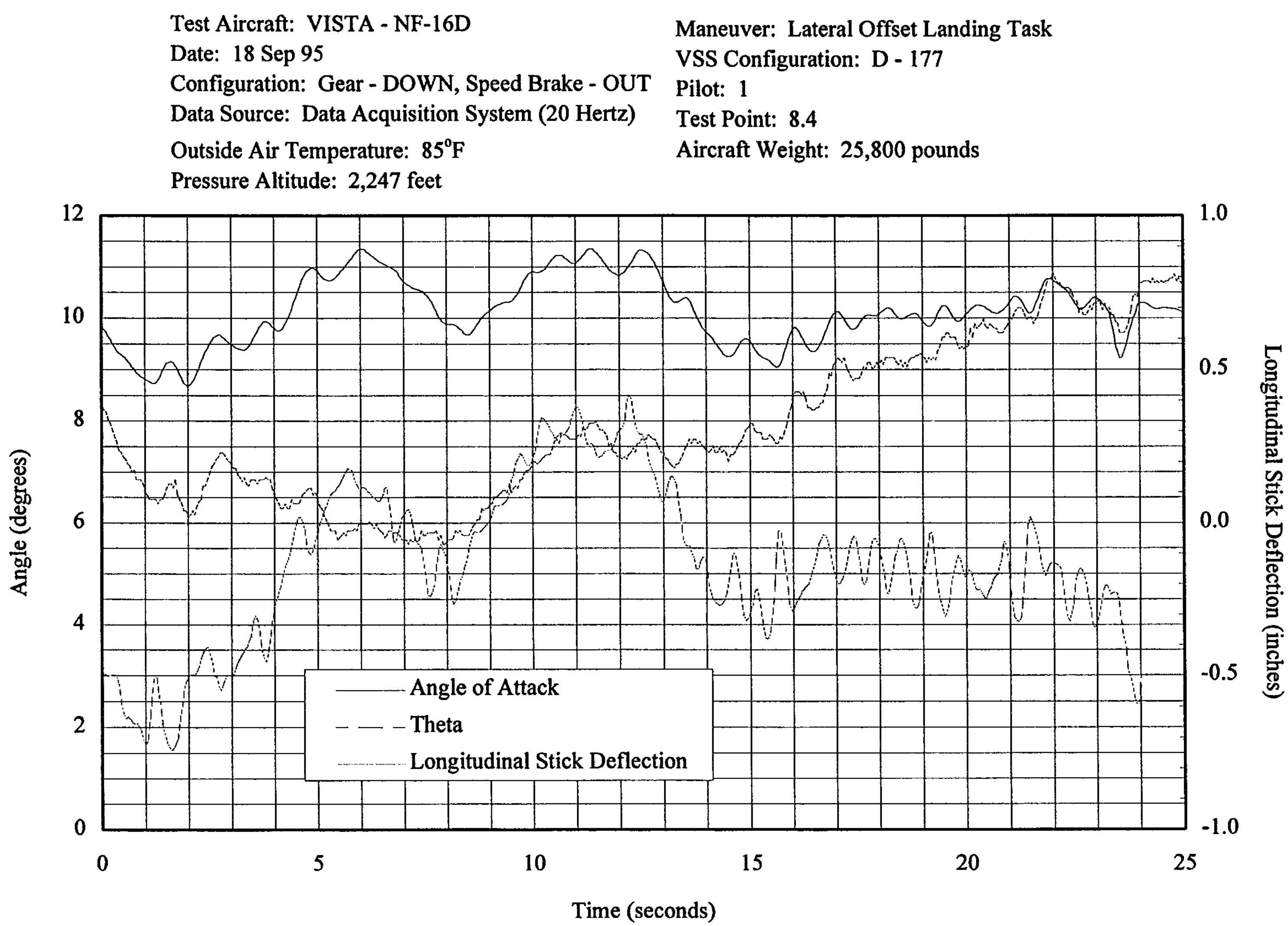

Figure J32 VSS Configuration D Time History of Theta and Longitudinal Stick Deflection

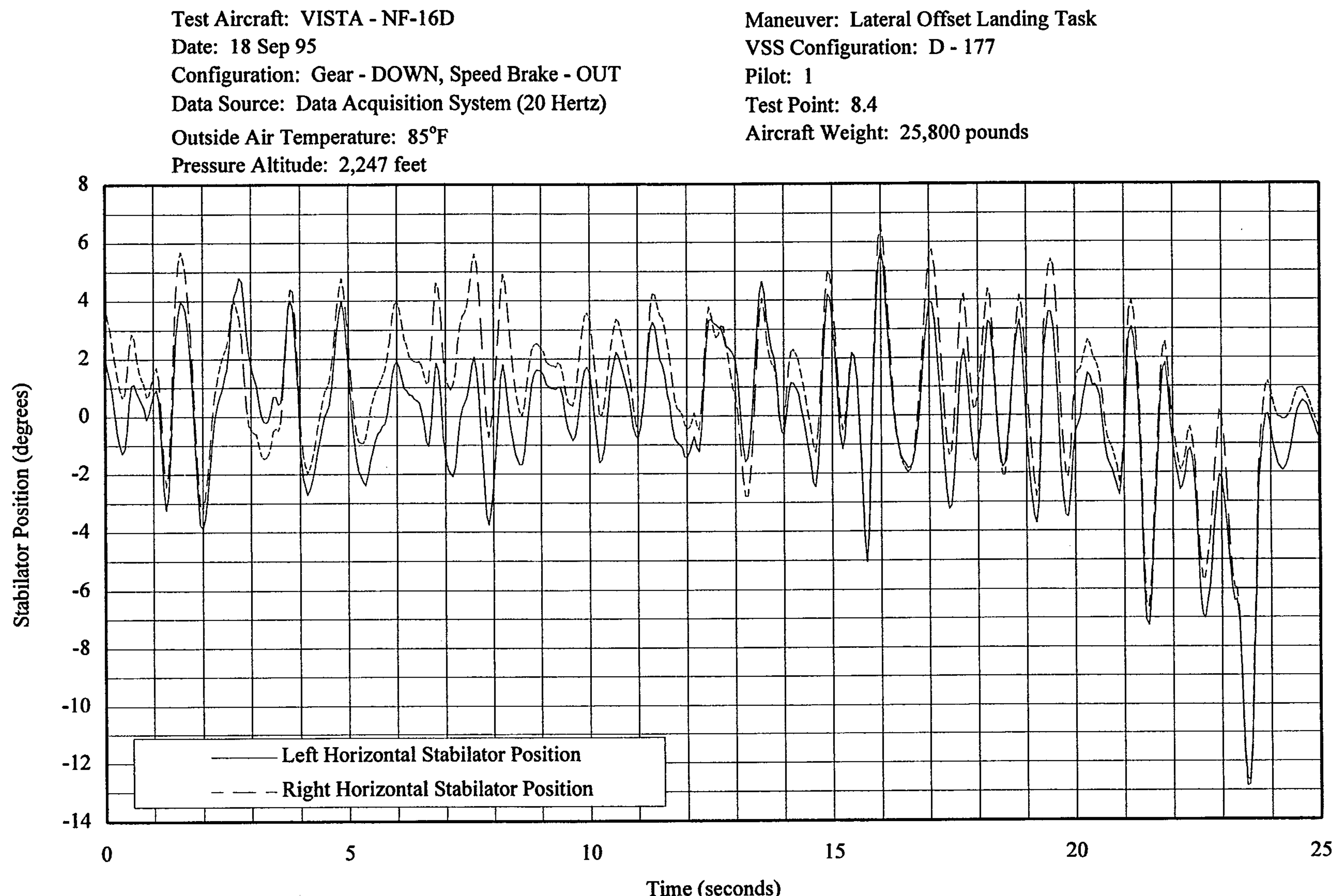

Figure J33 VSS Configuration D Time History of Stabilator Movement

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 85°F
Pressure Altitude: 2,247 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: D - 177
Pilot: 1
Test Point: 8.4
Aircraft Weight: 25,800 pounds

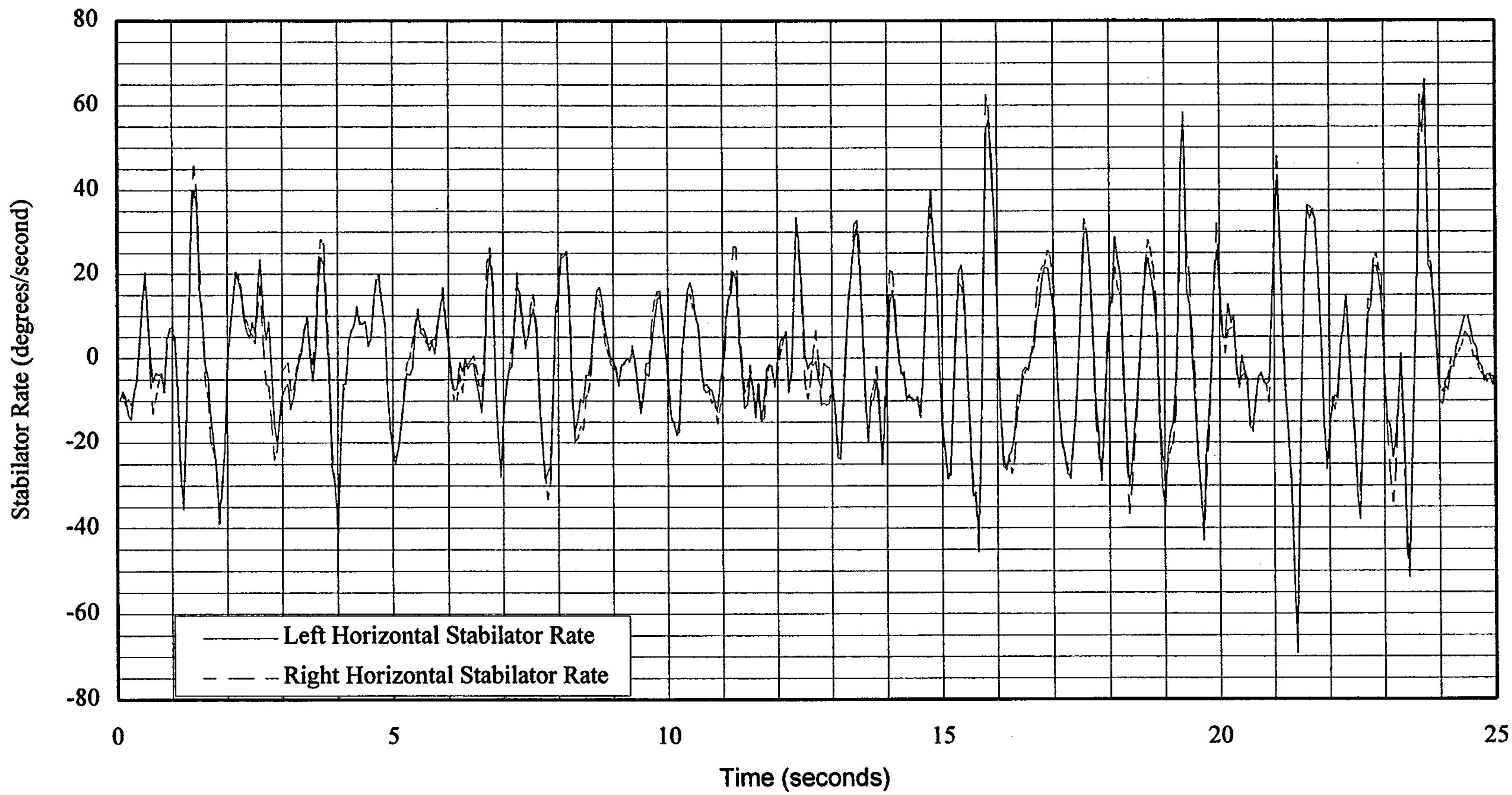

Figure J34 VSS Configuration D Time History of Stabilator Rate

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 85°F
Pressure Altitude: 2,247 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: D - 177
Pilot: 1
Test Point: 8.4
Aircraft Weight: 25,800 pounds

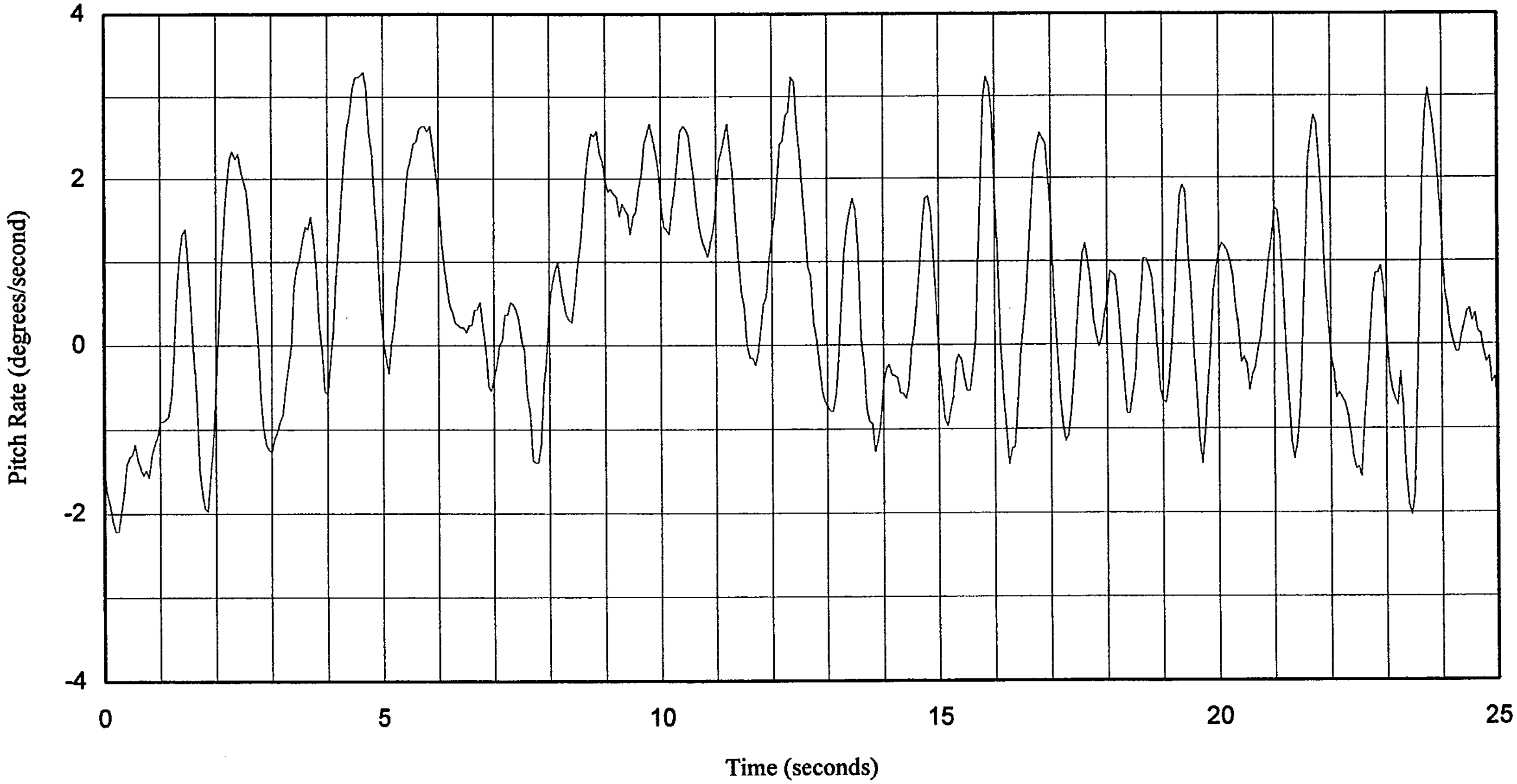

Figure J35 VSS Configuration D Time History of Pitch Rate

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 85°F
Pressure Altitude: 2,247 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: D - 177
Pilot: 1
Test Point: 8.4
Aircraft Weight: 25,800 pounds

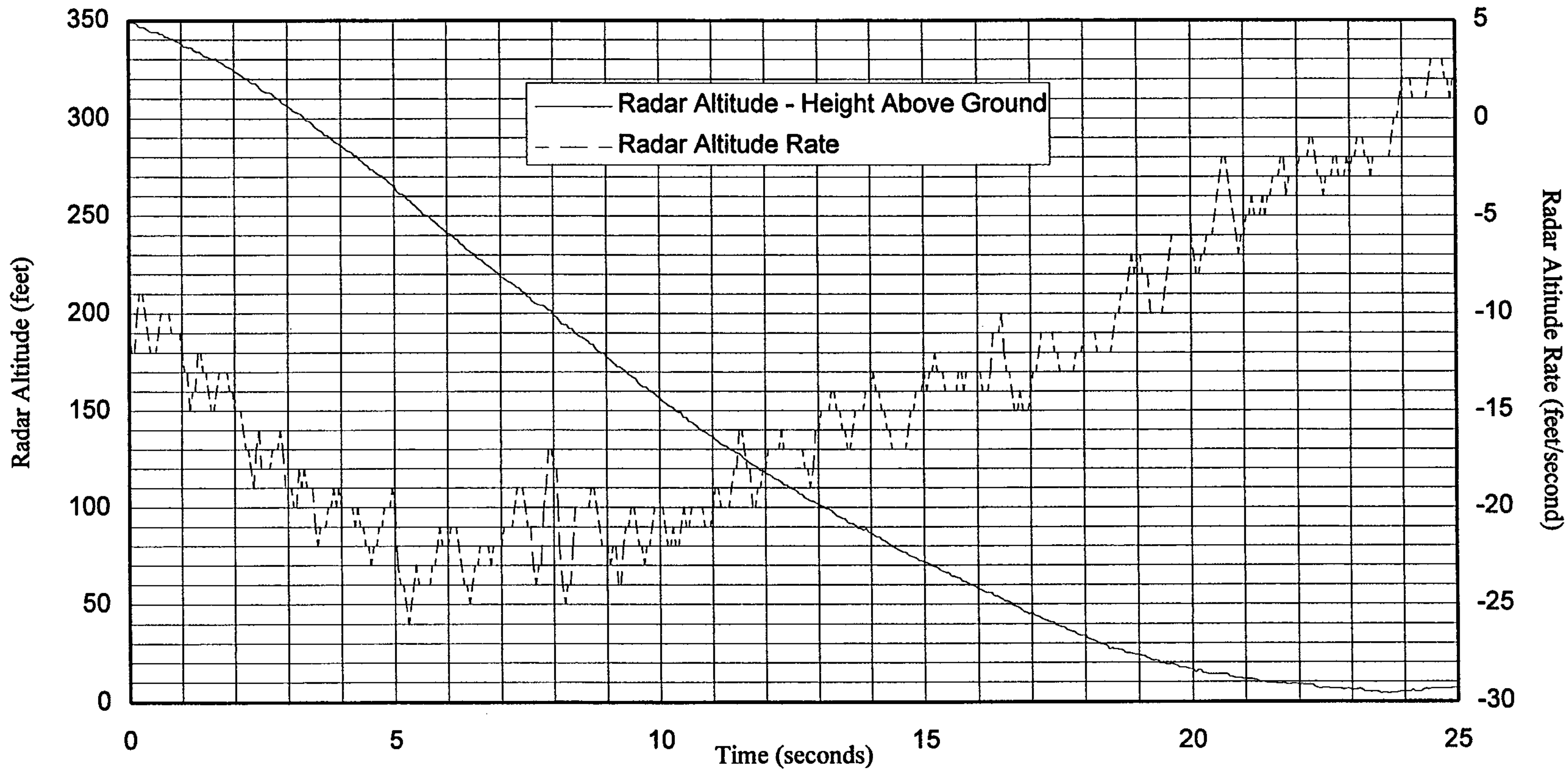

Figure J36 VSS Configuration D Time History of Altitude and Descent Rate

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 85°F
Pressure Altitude: 2,247 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: D - 177
Pilot: 1
Test Point: 8.4
Aircraft Weight: 25,800 pounds

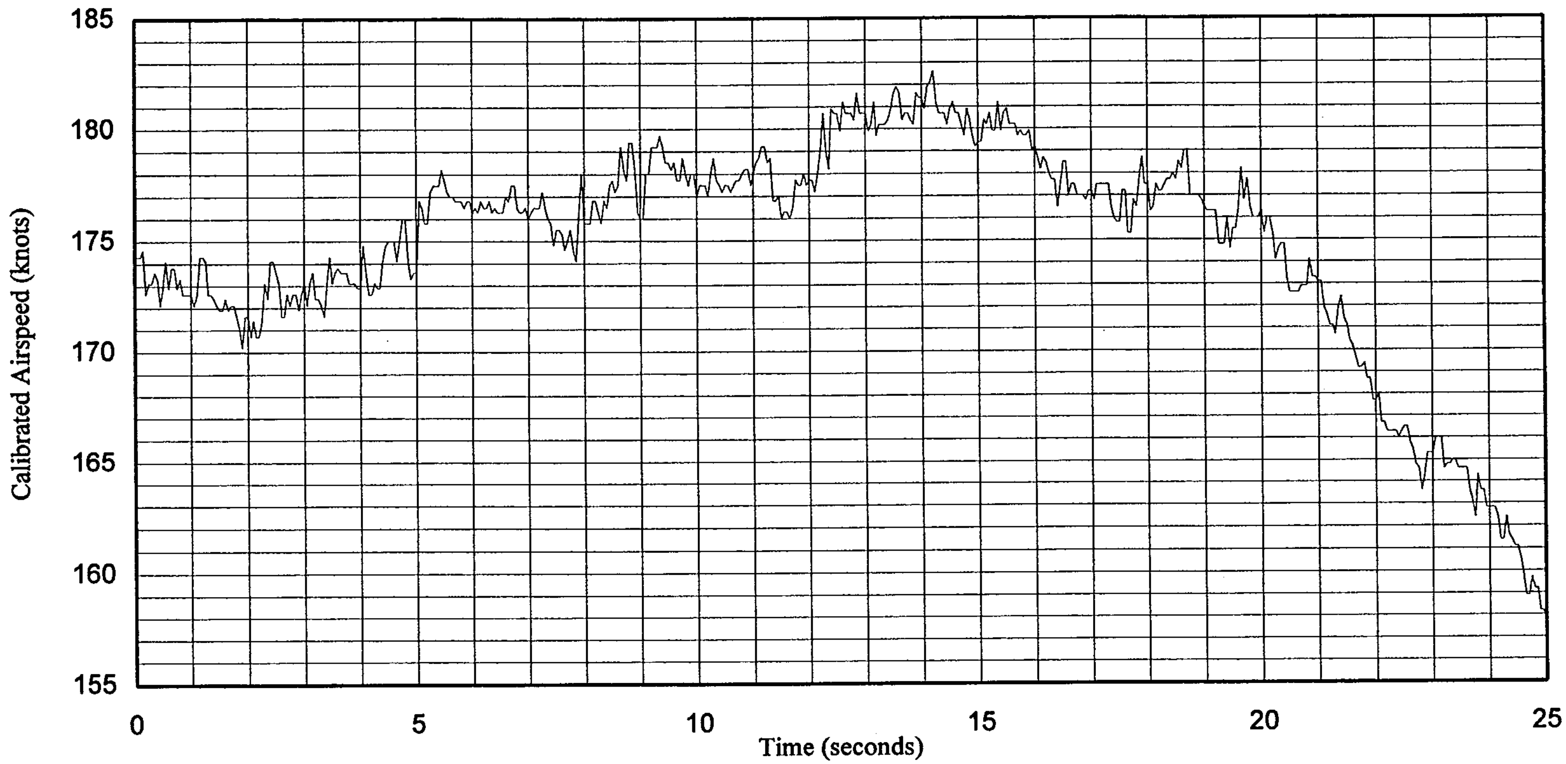

Figure J37 VSS Configuration D Time History of Calibrated Airspeed

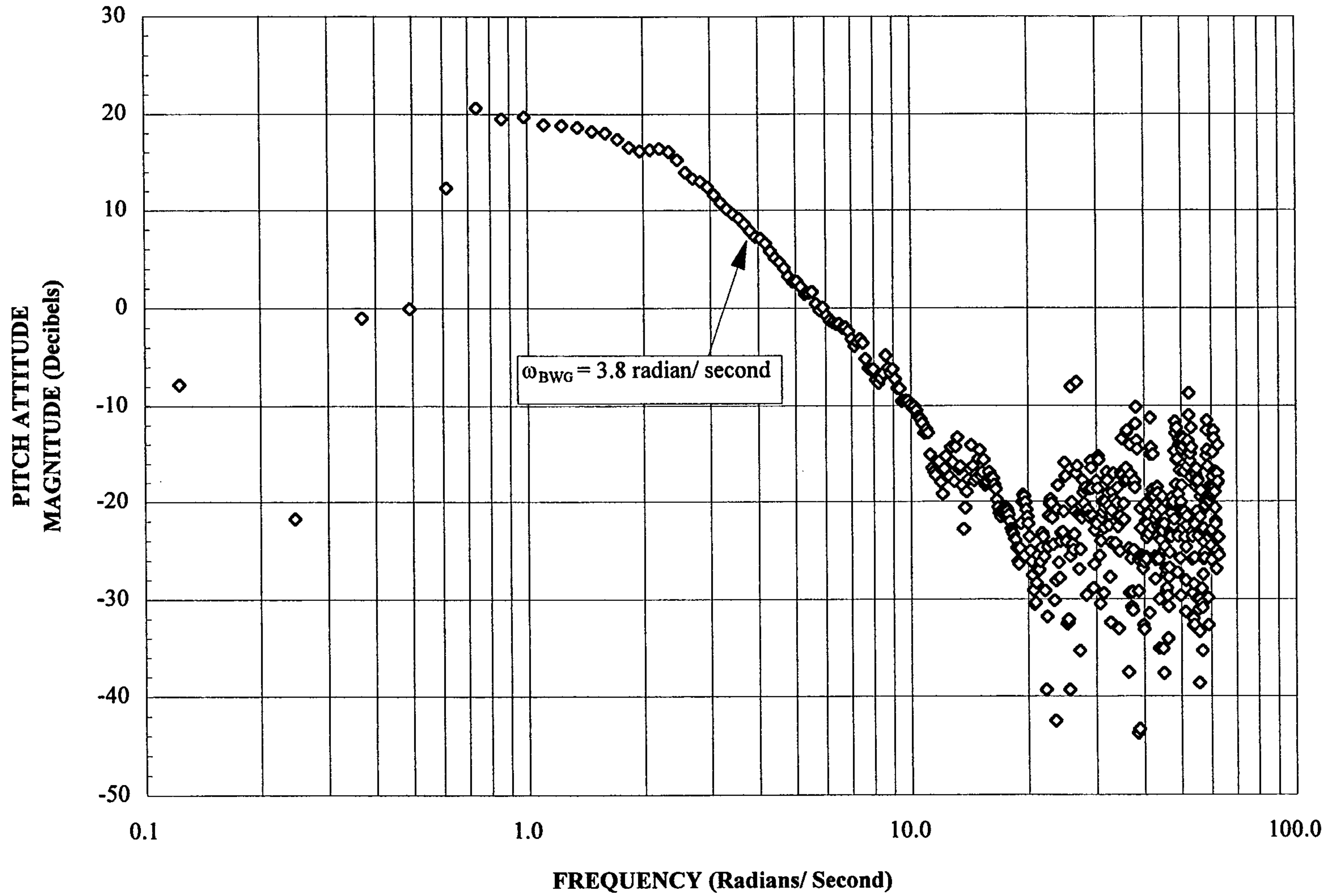

Figure J38 VSS Configuration E Magnitude Bode Plot

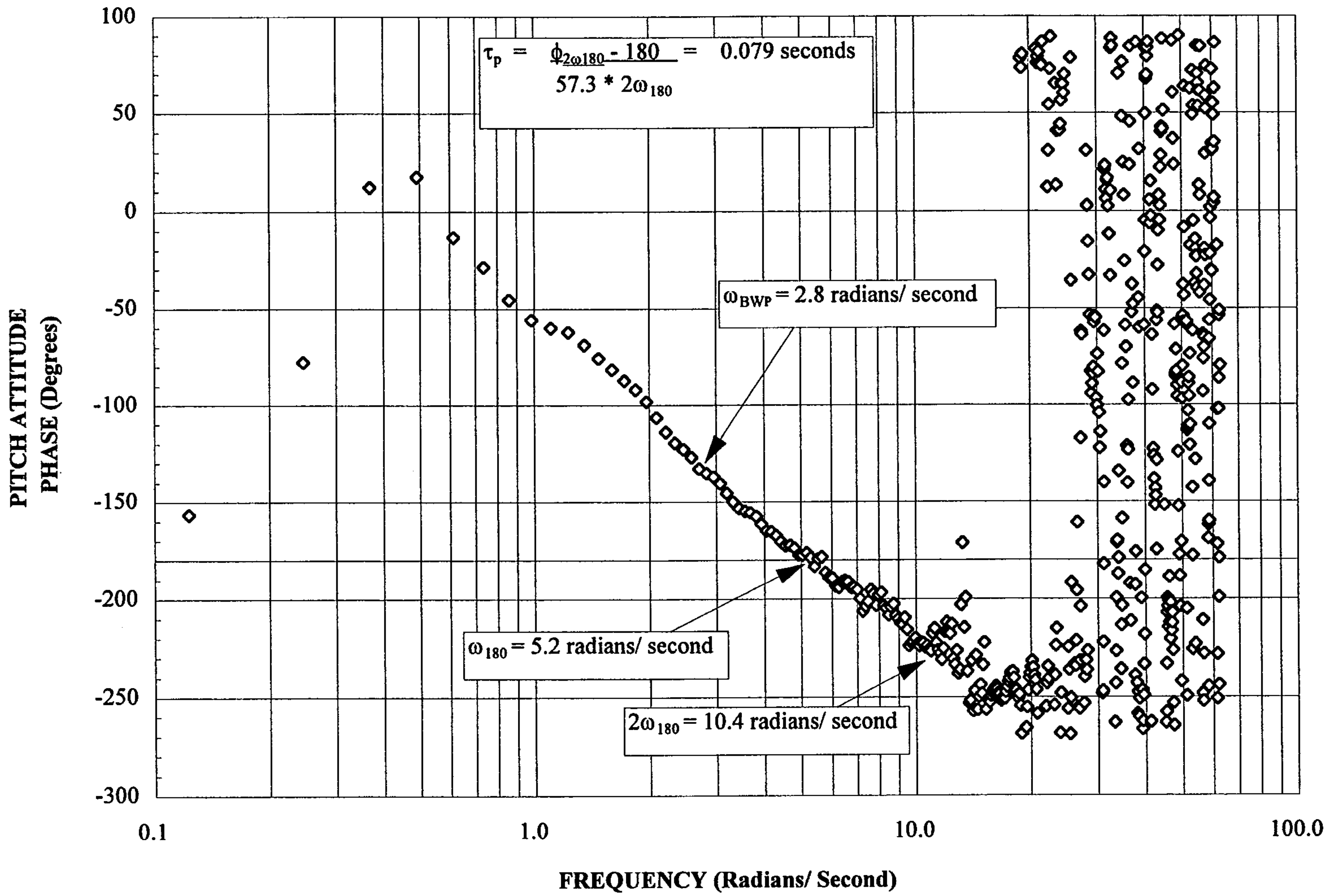

Figure J39 VSS Configuration E Phase Bode Plot

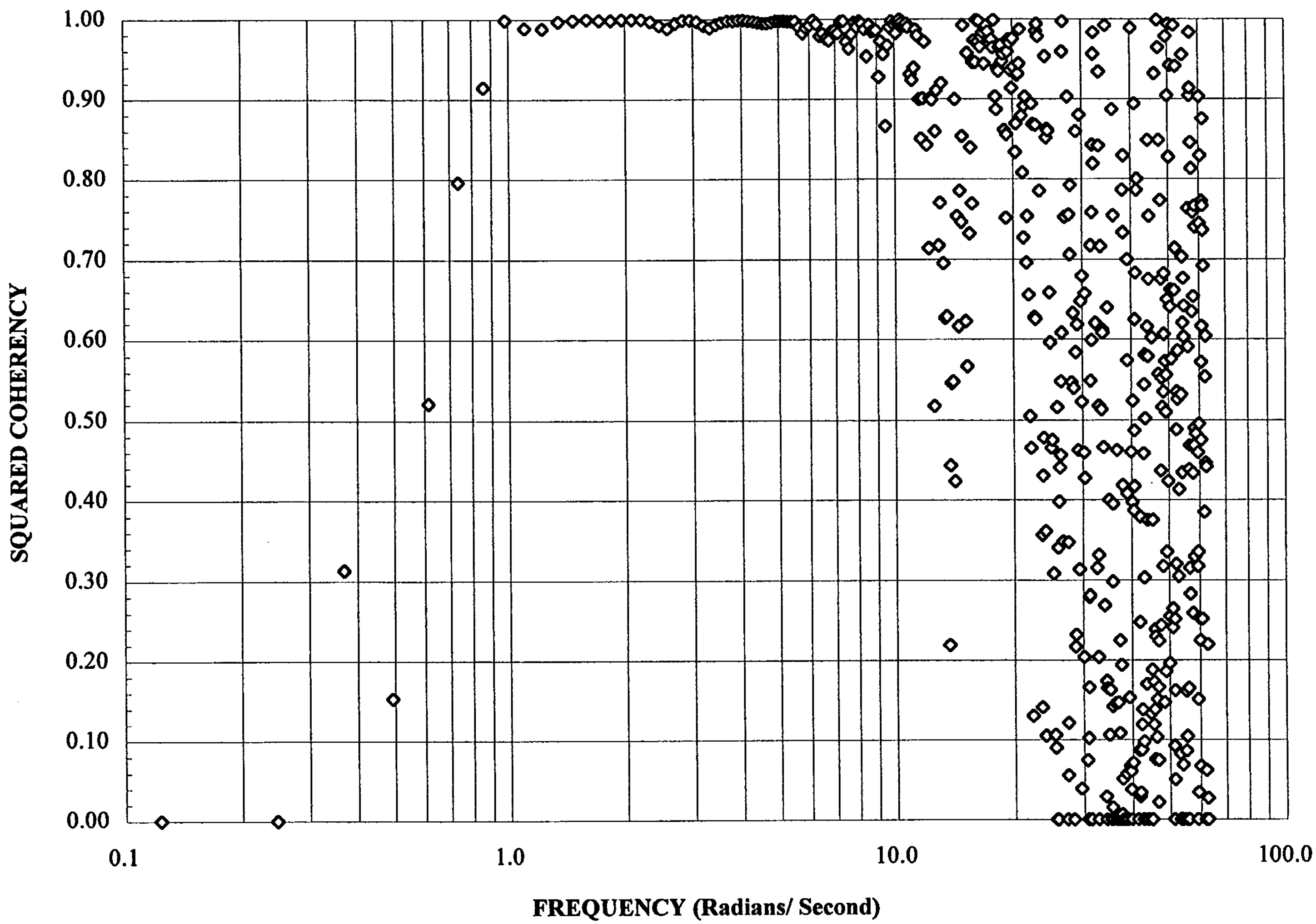

Figure J40 VSS Configuration E Bode Squared Coherency Plot

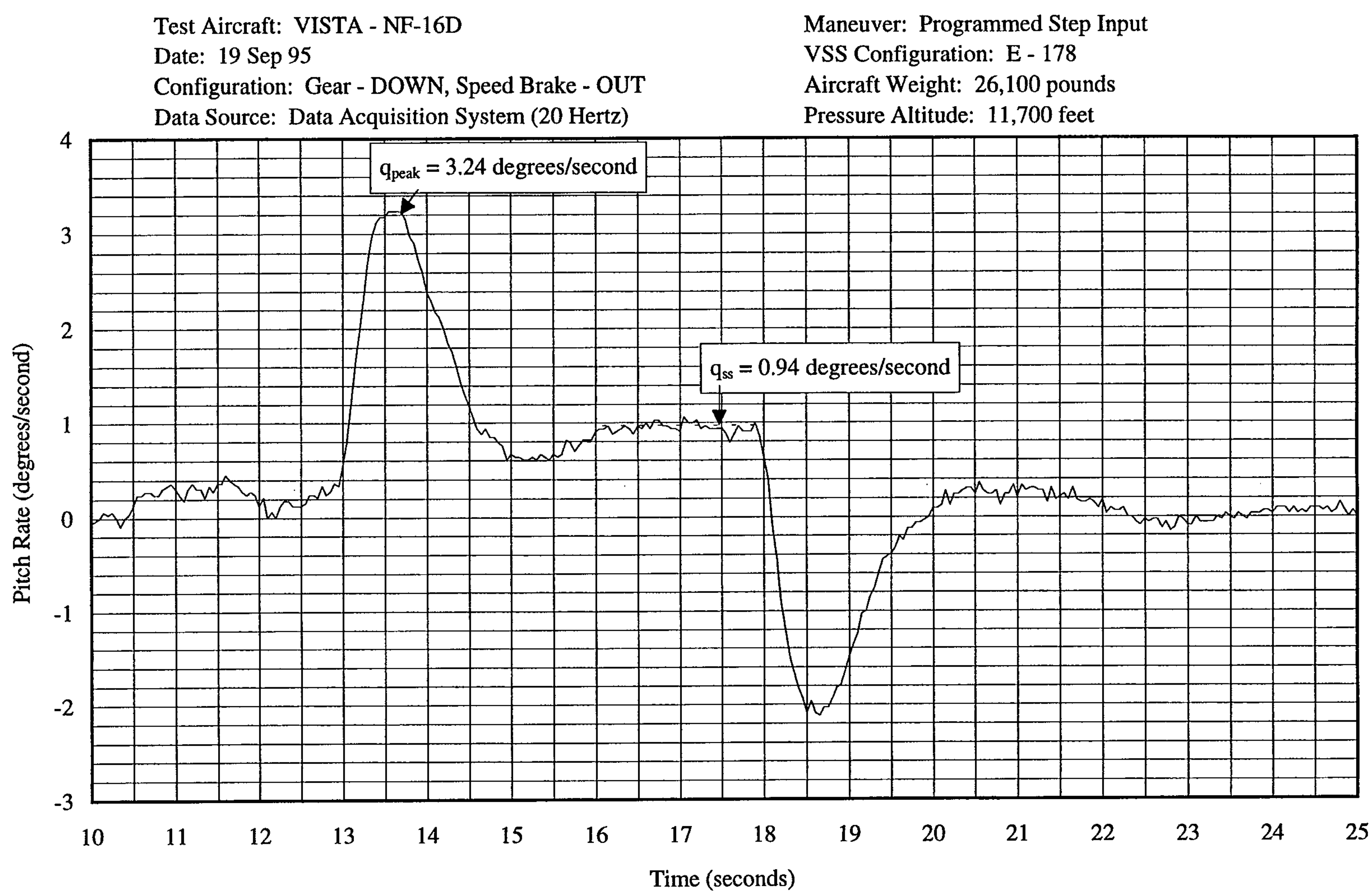

Figure J41 VSS Configuration E Pitch Rate Dropback

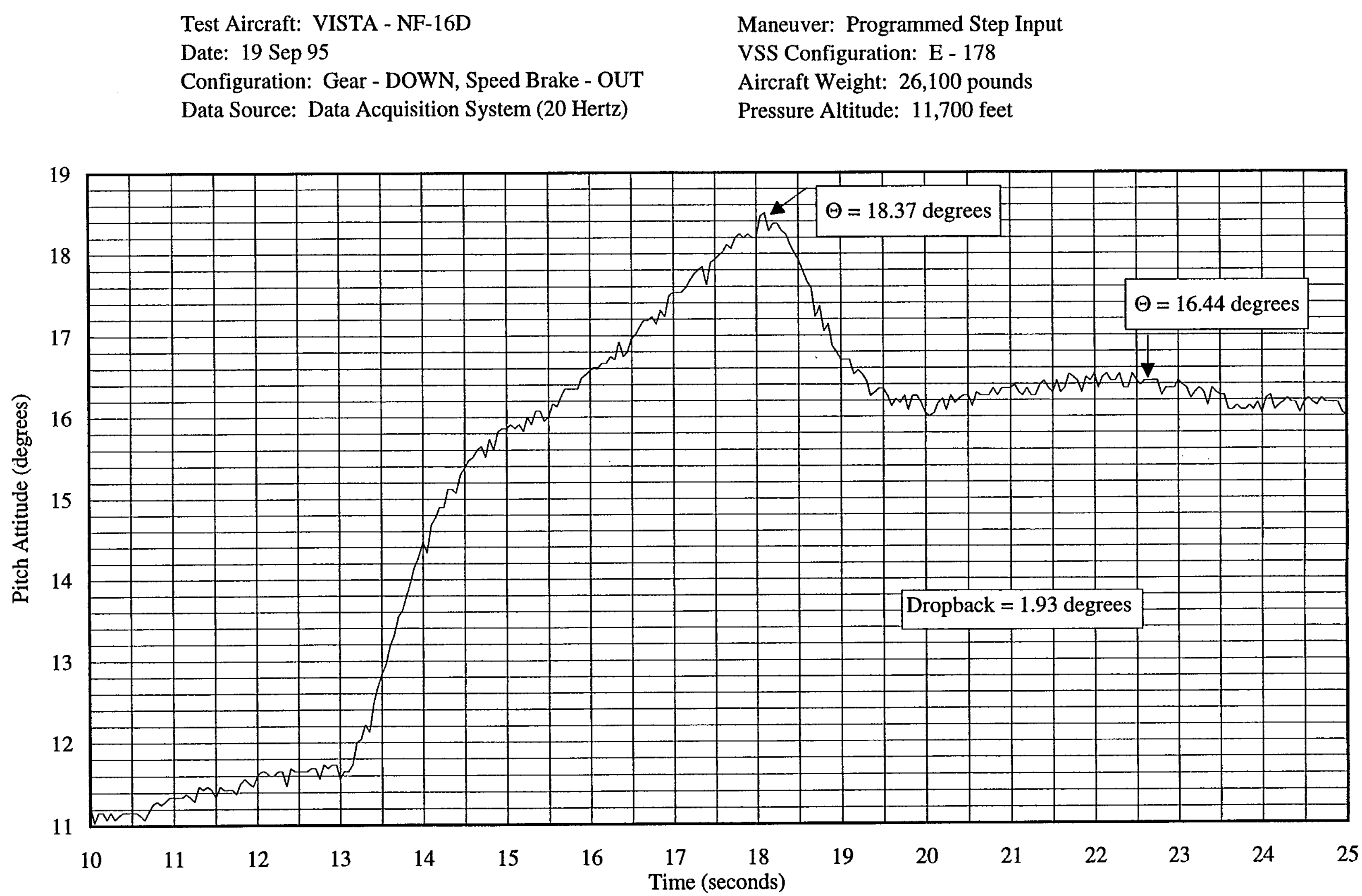

Figure J42 VSS Configuration E Pitch Angle Dropback

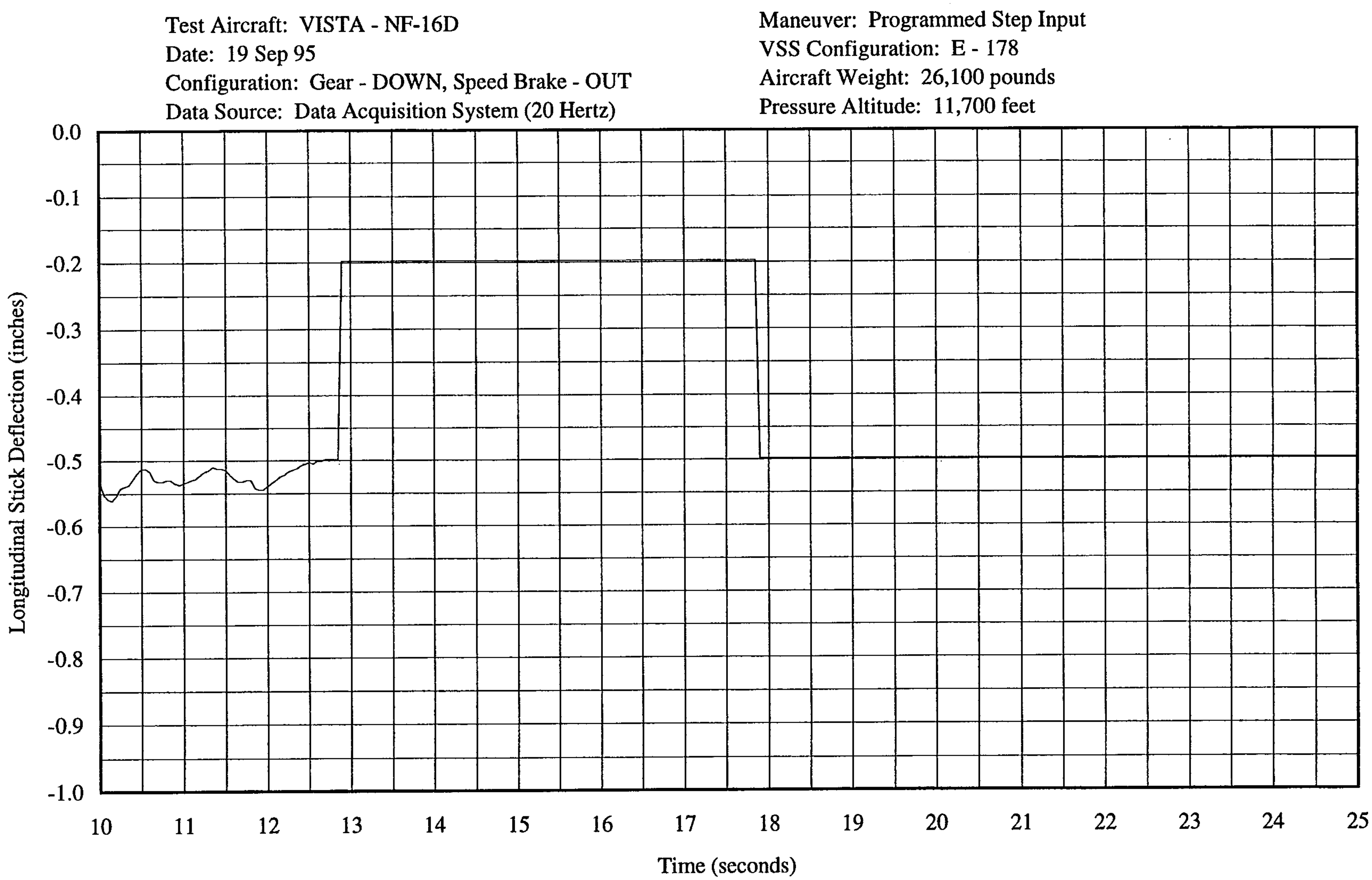

Figure J43 VSS Configuration E Pitch Input Dropback

Test Aircraft: VISTA - NF-16D
Date: 16 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 98°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: E - 178
Pilot: 3
Test Point: 5.6
Aircraft Weight: 24,000 pounds

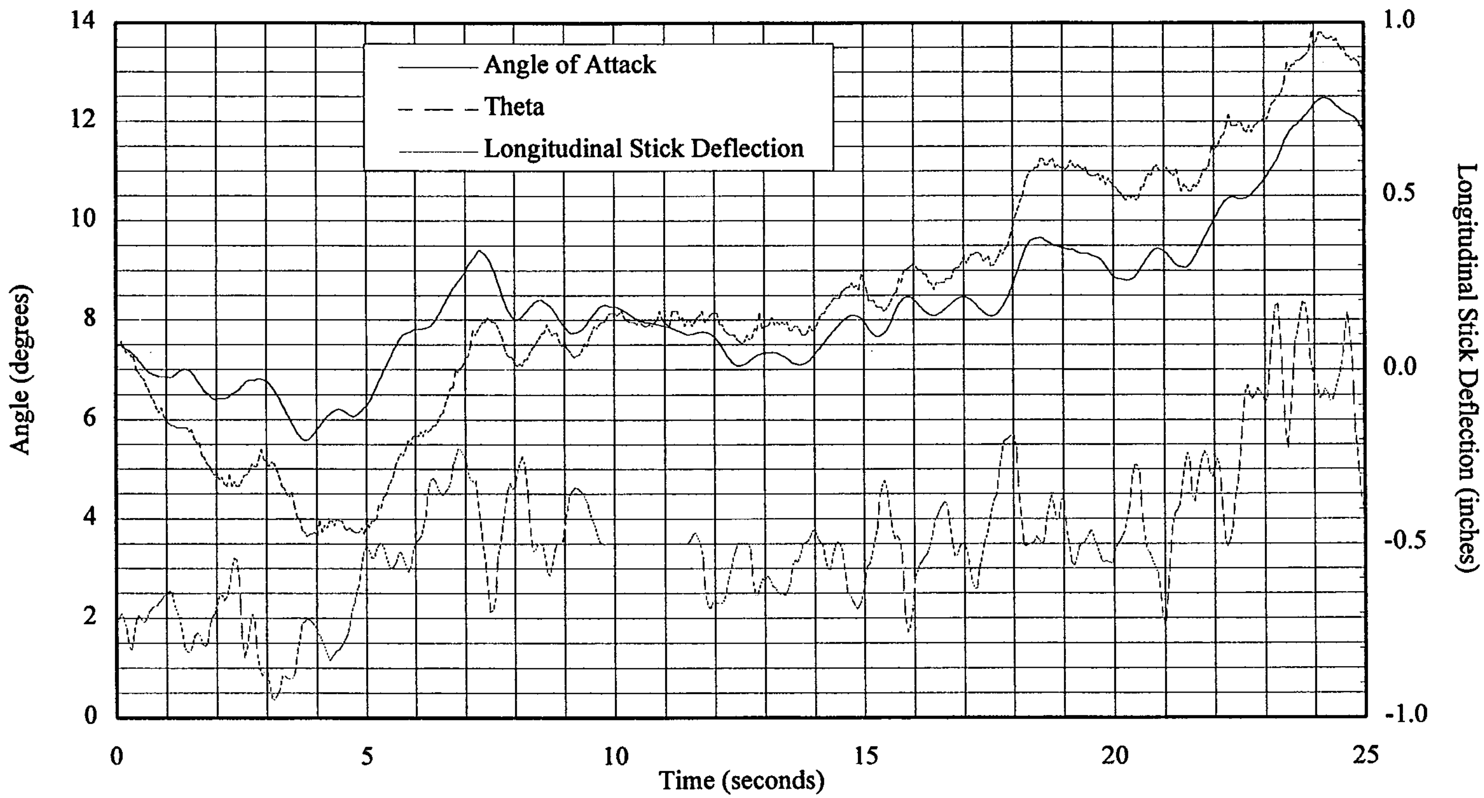

Figure J44 VSS Configuration E Time History of Theta and Longitudinal Stick Deflection

Test Aircraft: VISTA - NF-16D
Date: 16 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 98°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: E - 178
Pilot: 3
Test Point: 5.6
Aircraft Weight: 24,000 pounds

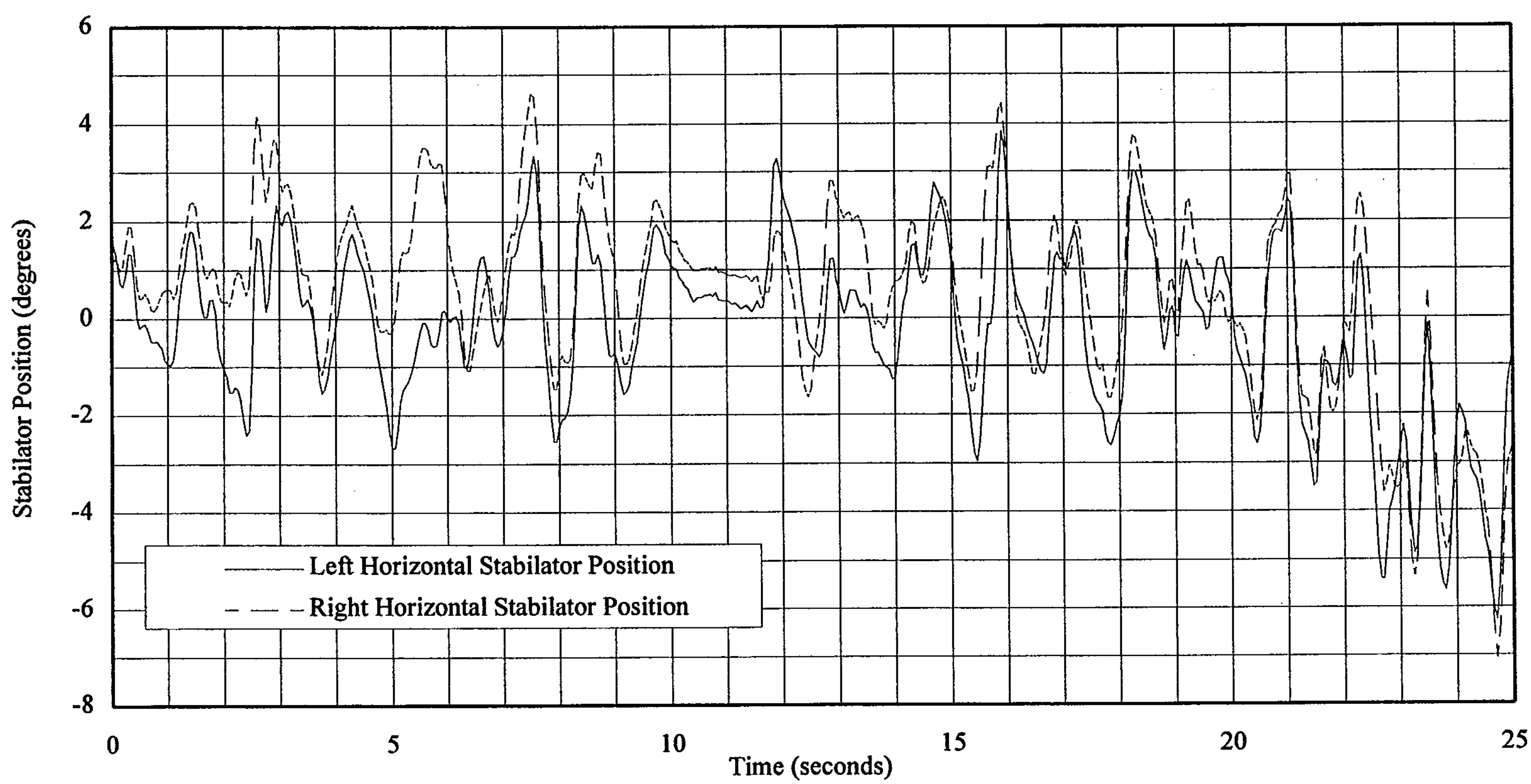

Figure J45 VSS Configuration E Time History of Stabilator Movement

Test Aircraft: VISTA - NF-16D
Date: 16 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 98°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: E - 178
Pilot: 3
Test Point: 5.6
Aircraft Weight: 24,000 pounds

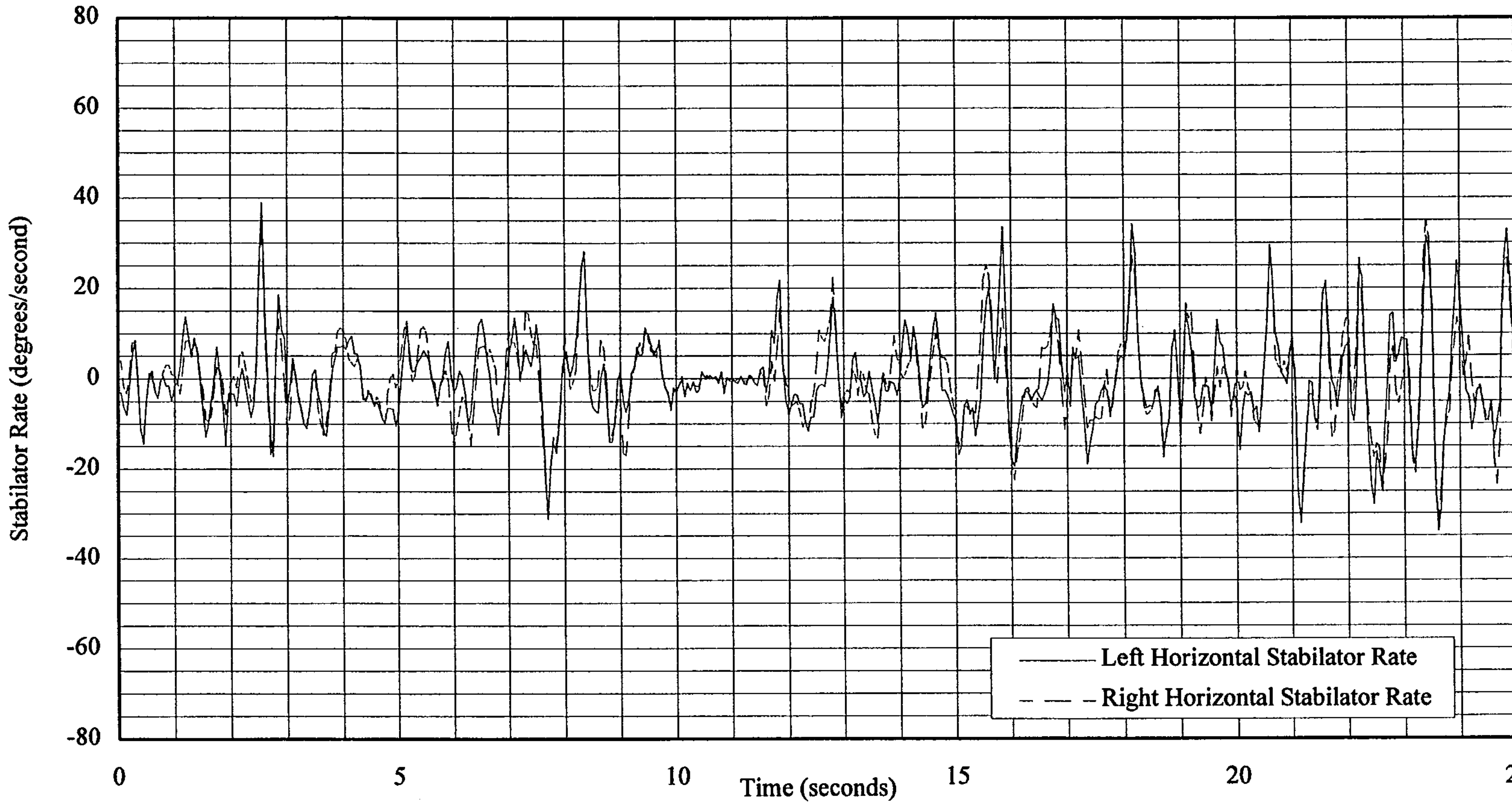

Figure J46 VSS Configuration E Time History of Stabilator Rate

Test Aircraft: VISTA - NF-16D
Date: 16 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 98°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: E - 178
Pilot: 3
Test Point: 5.6
Aircraft Weight: 24,000 pounds

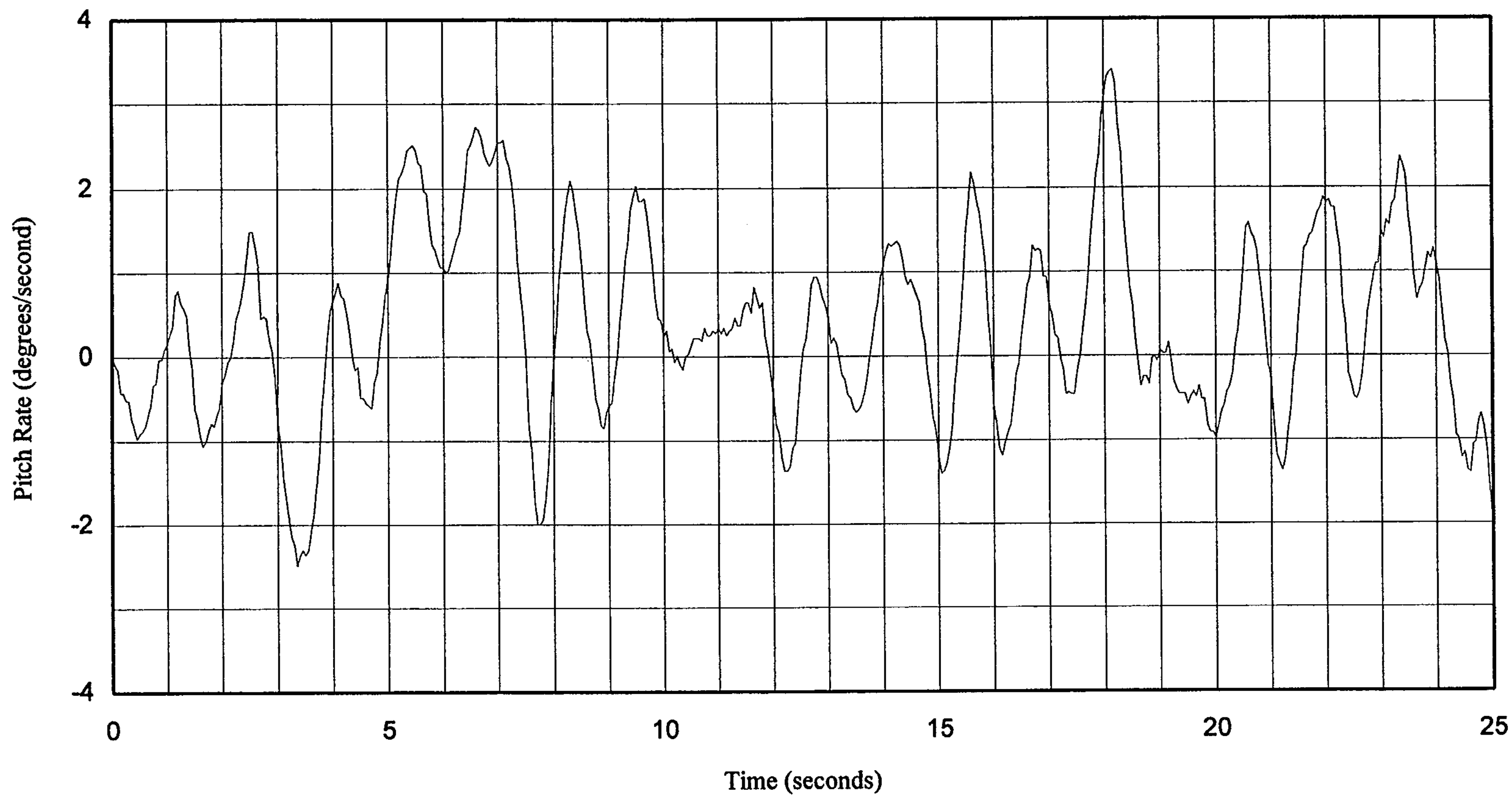

Figure J47 VSS Configuration E Time History of Pitch Rate

Test Aircraft: VISTA - NF-16D	Maneuver: Lateral Offset Landing Task
Date: 16 Sep 95	VSS Configuration: E - 178
Configuration: Gear - DOWN, Speed Brake - OUT	Pilot: 3
Data Source: Data Acquisition System (20 Hertz)	Test Point: 5.6
Outside Air Temperature: 98°F	Aircraft Weight: 24,000 pounds

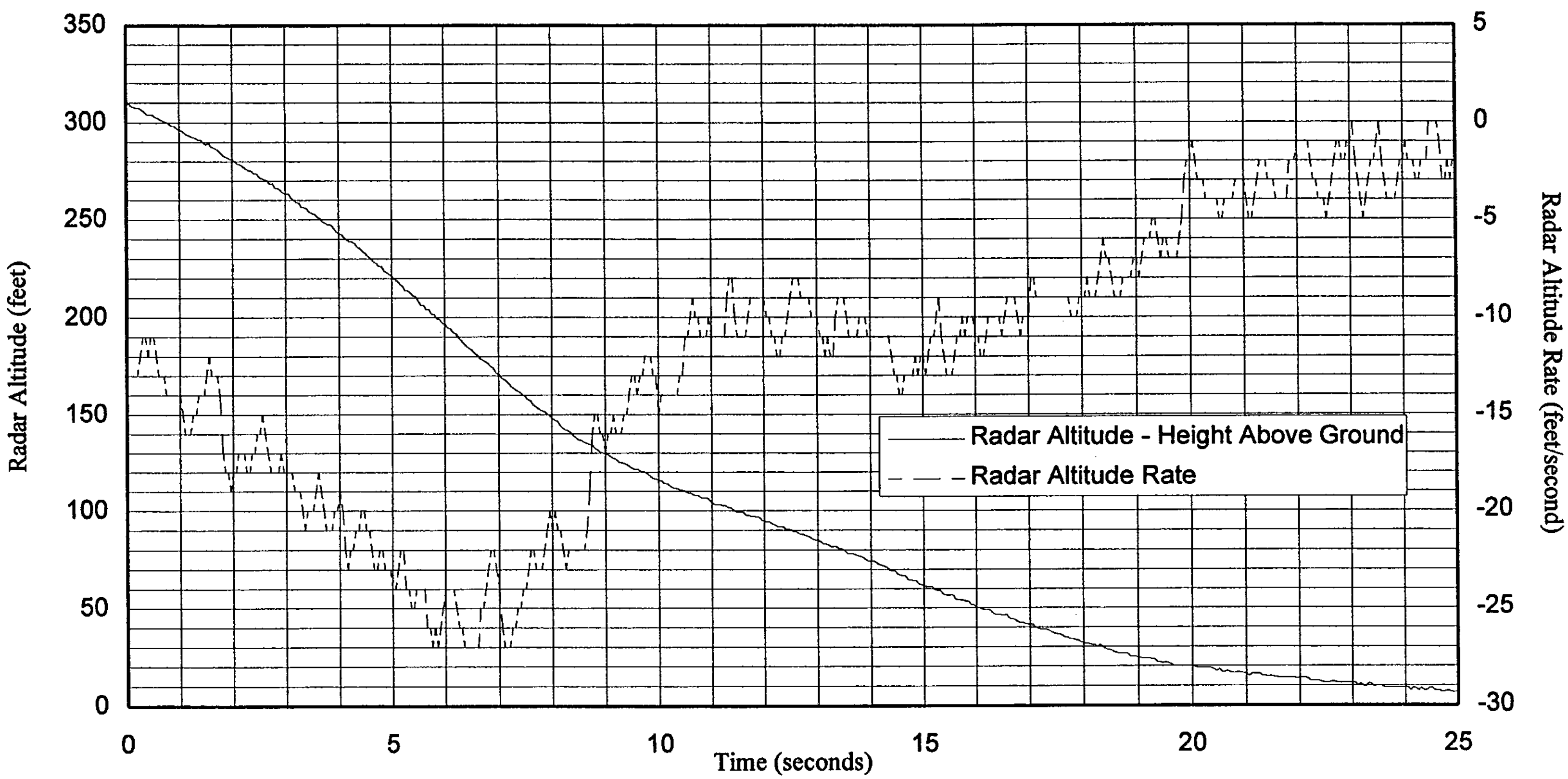

Figure J48 VSS Configuration E Time History of Altitude and Descent Rate

Test Aircraft: VISTA - NF-16D
Date: 16 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 98°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: E - 178
Pilot: 3
Test Point: 5.6
Aircraft Weight: 24,000 pounds

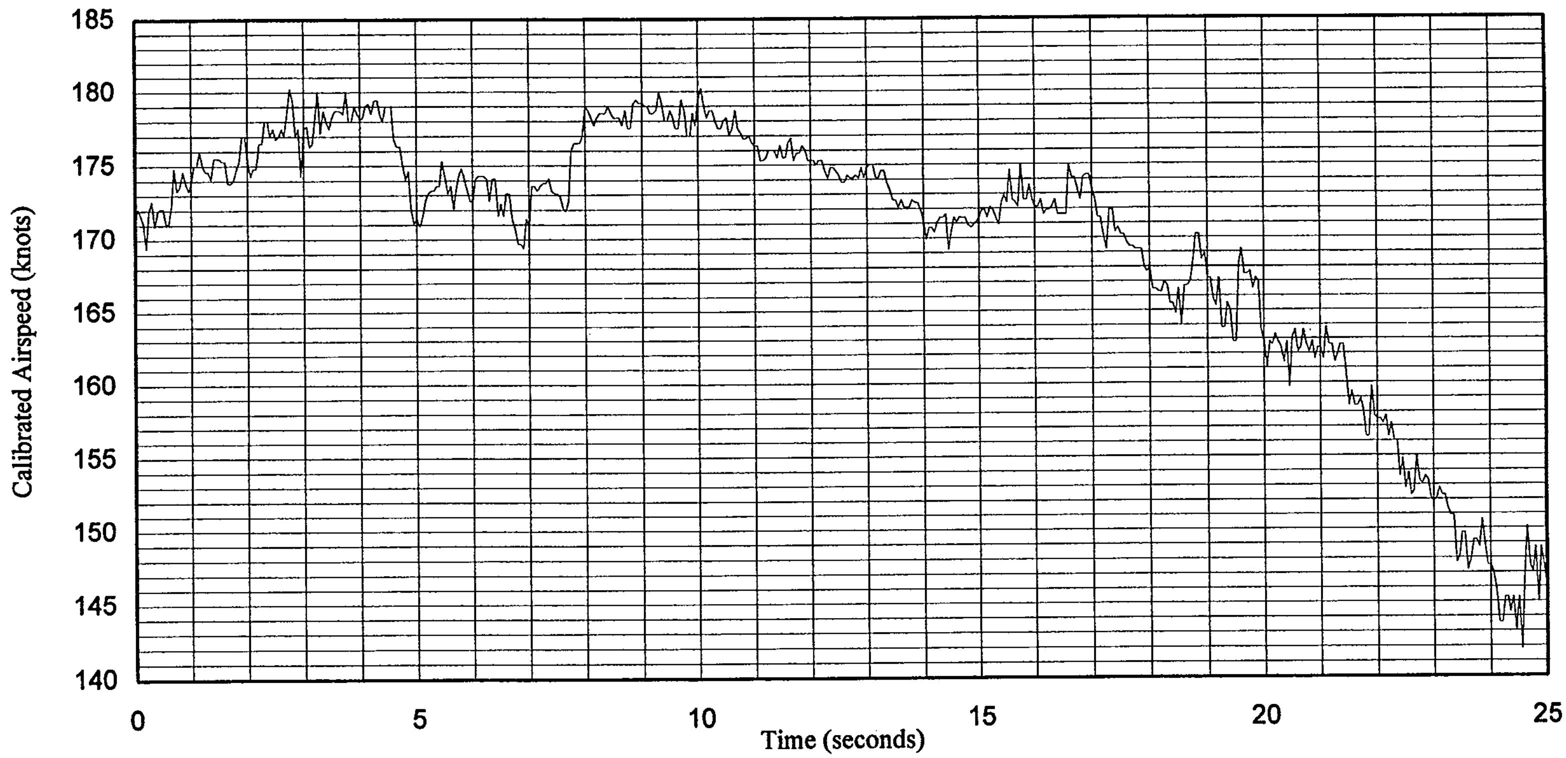

Figure J49 VSS Configuration E Time History of Calibrated Airspeed

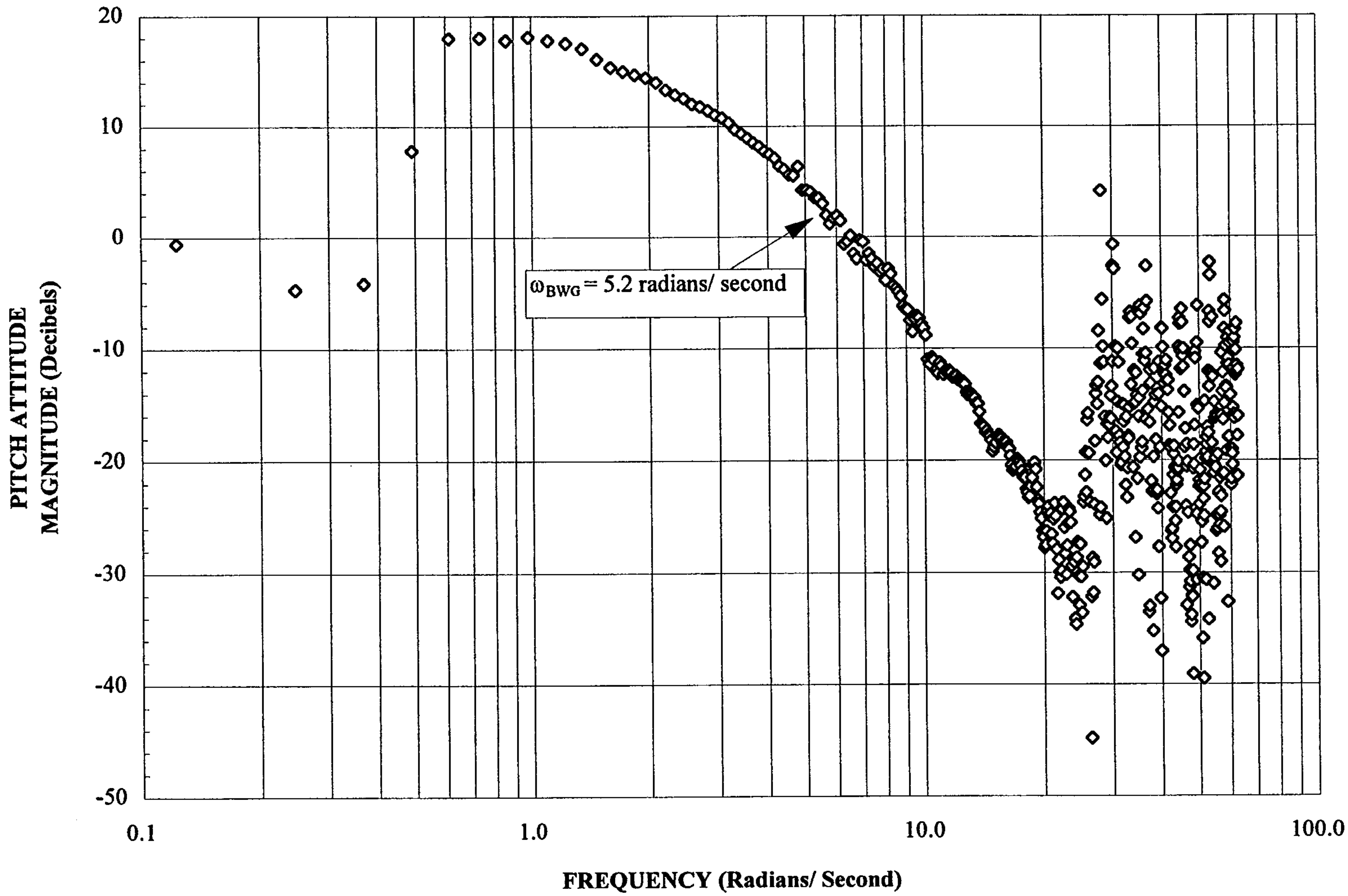

Figure J50 VSS Configuration G Magnitude Bode Plot

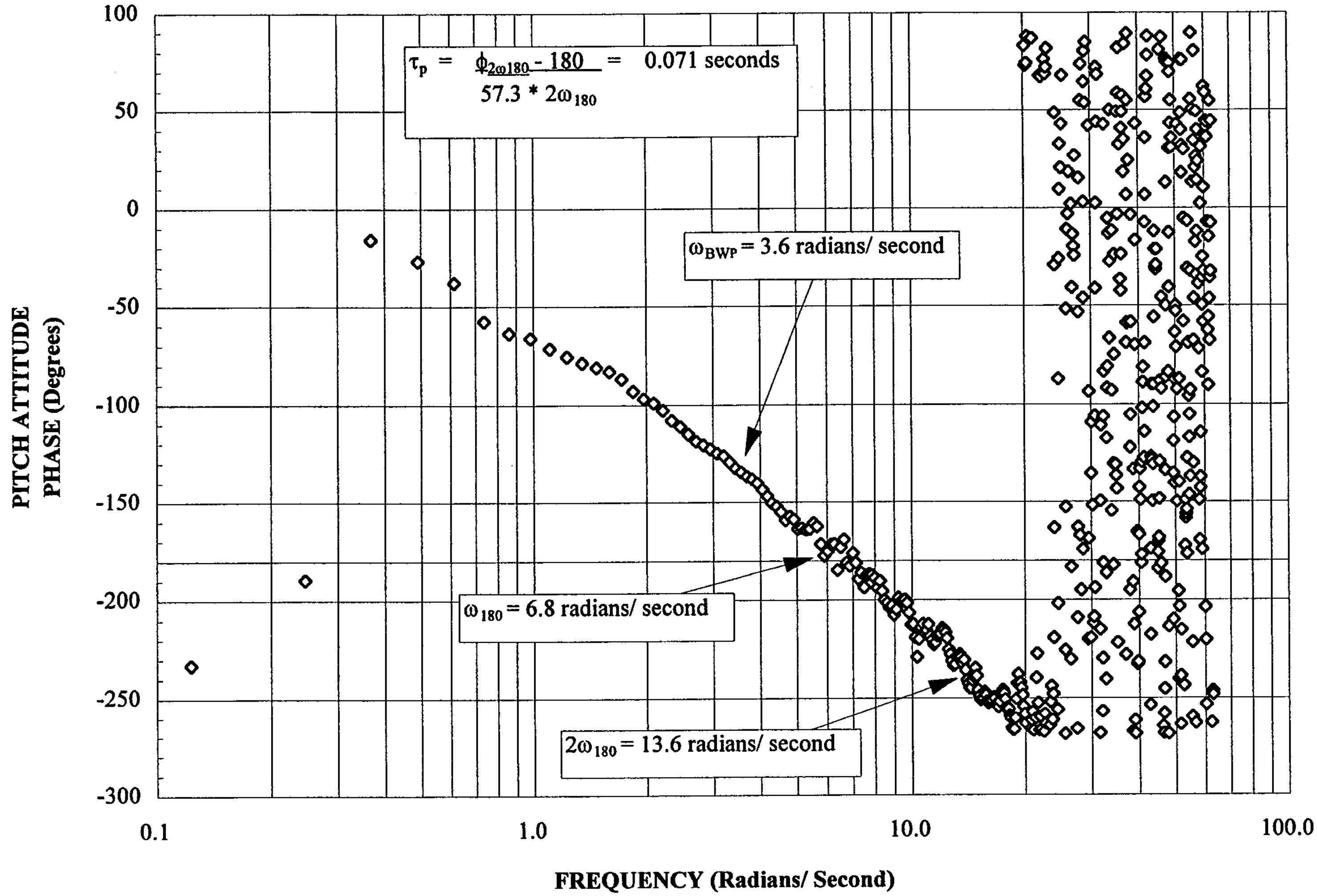

Figure J51 VSS Configuration G Phase Bode Plot

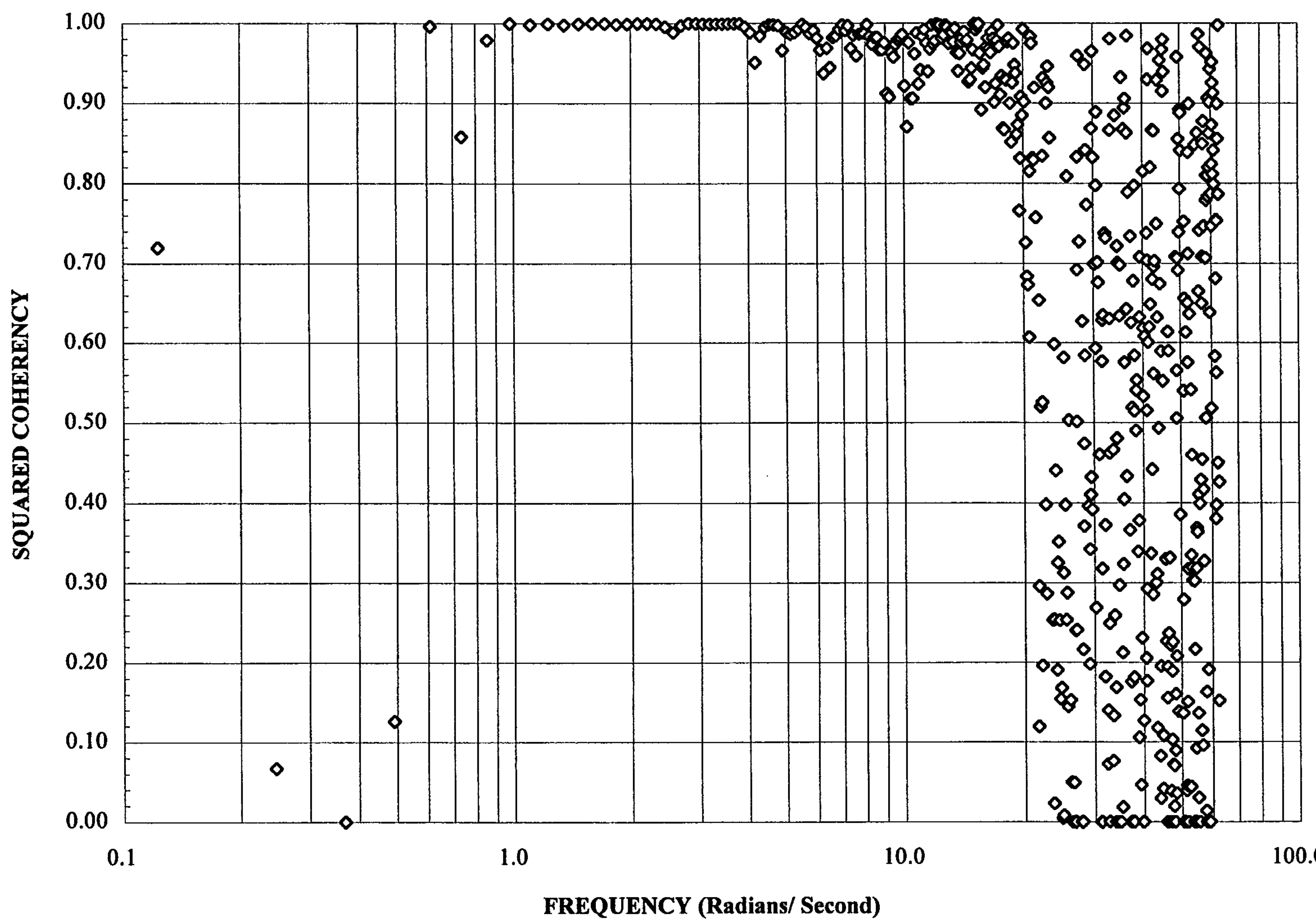

Figure J52 VSS Configuration G Bode Squared Coherency Plot

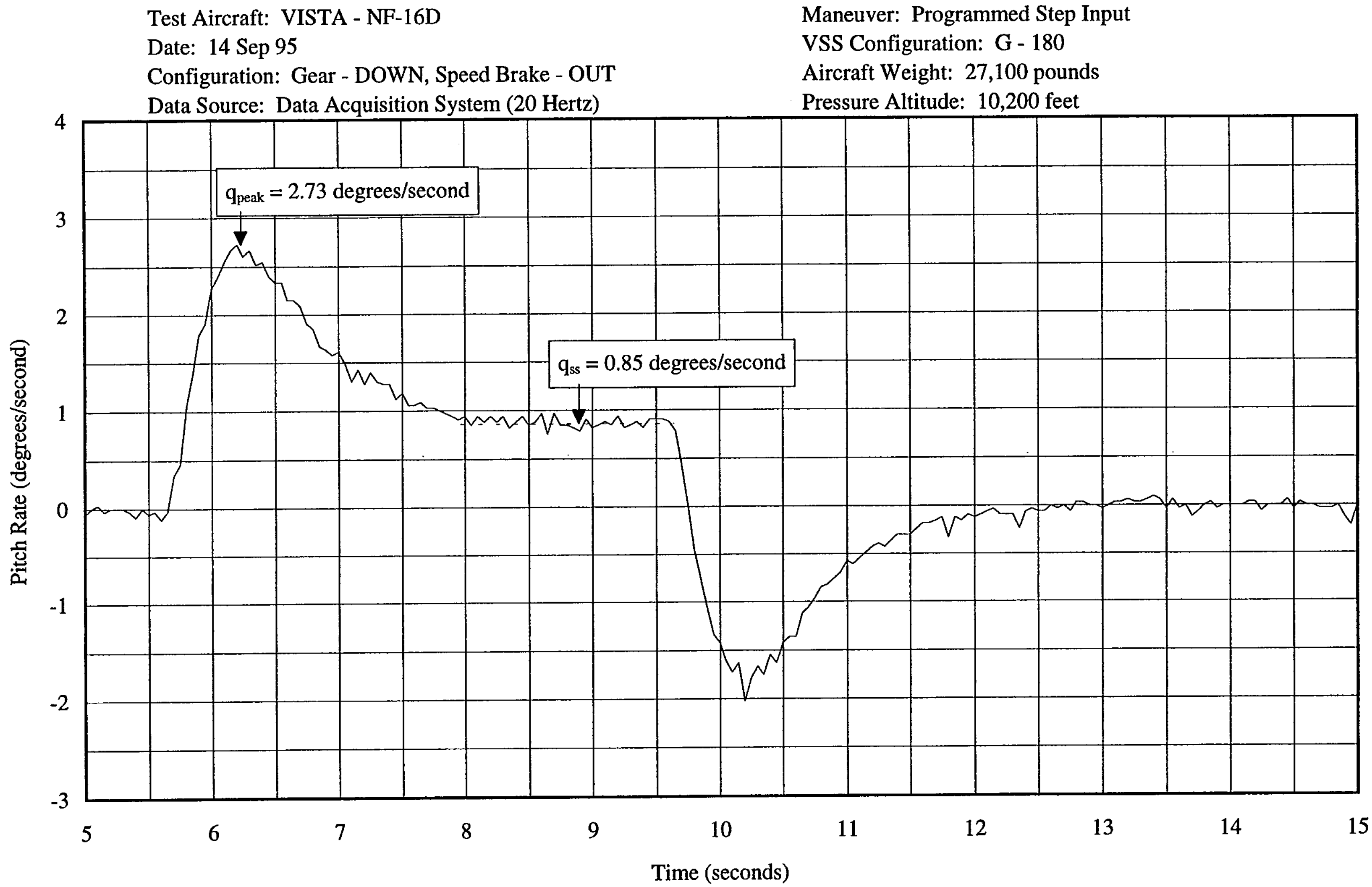

Figure J53 VSS Configuration G Pitch Rate Dropback

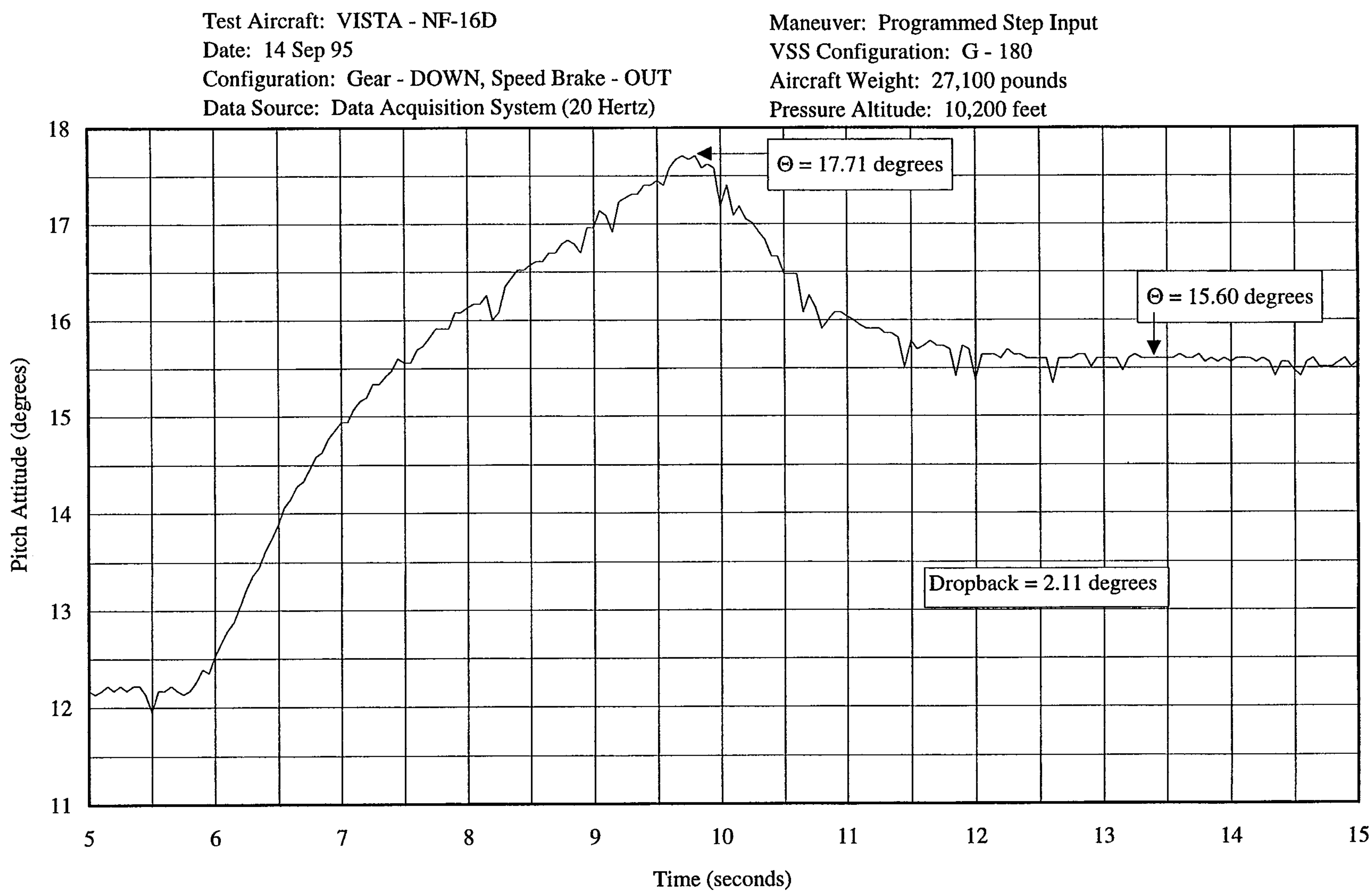

Figure J54 VSS Configuration G Pitch Angle Dropback

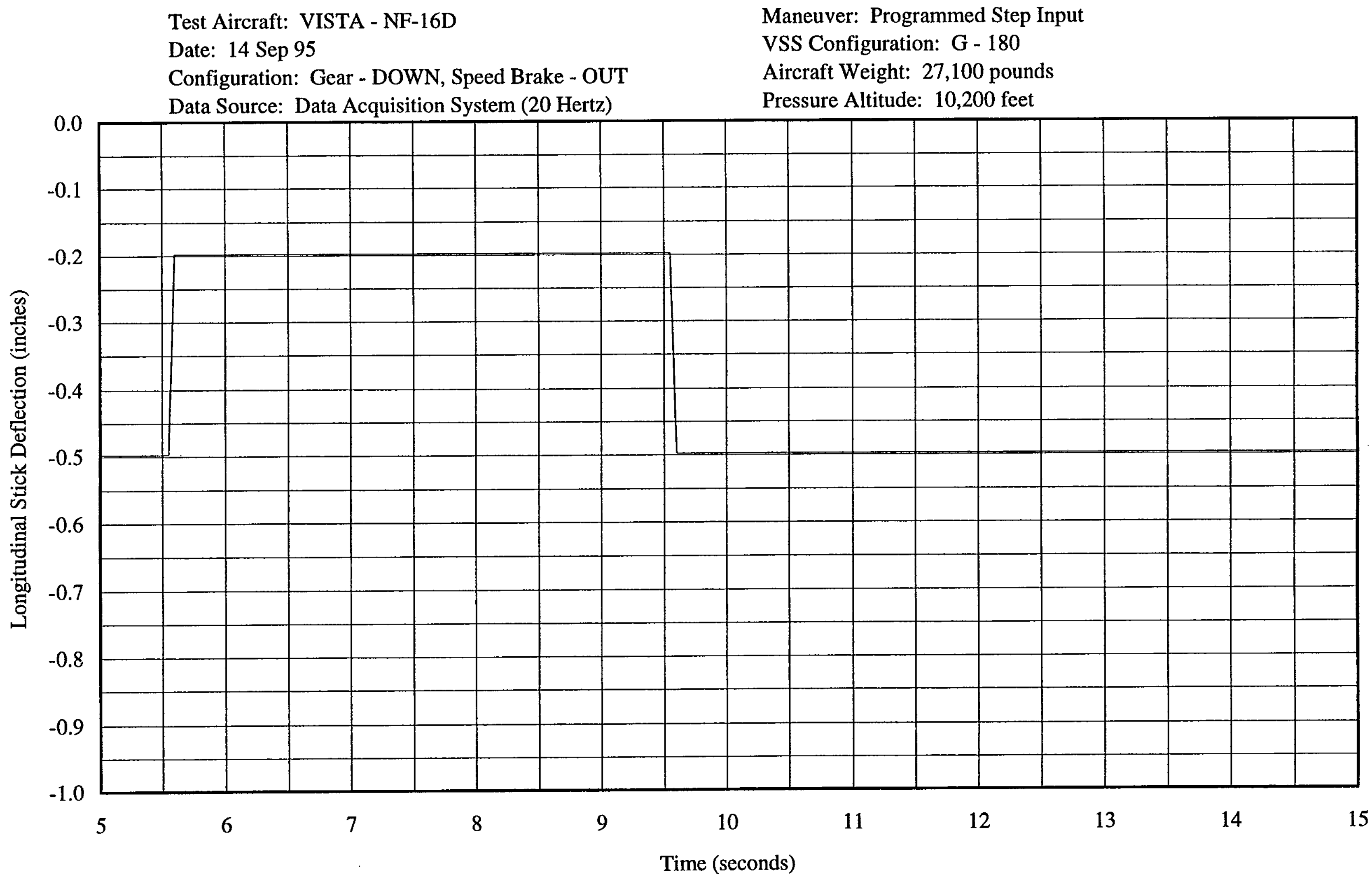

Figure J55 VSS Configuration G Pitch Input Dropback

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 88°F
Pressure Altitude: 2,257 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: G - 180
Pilot: 1
Test Point: 8.5
Aircraft Weight: 24,400 pounds

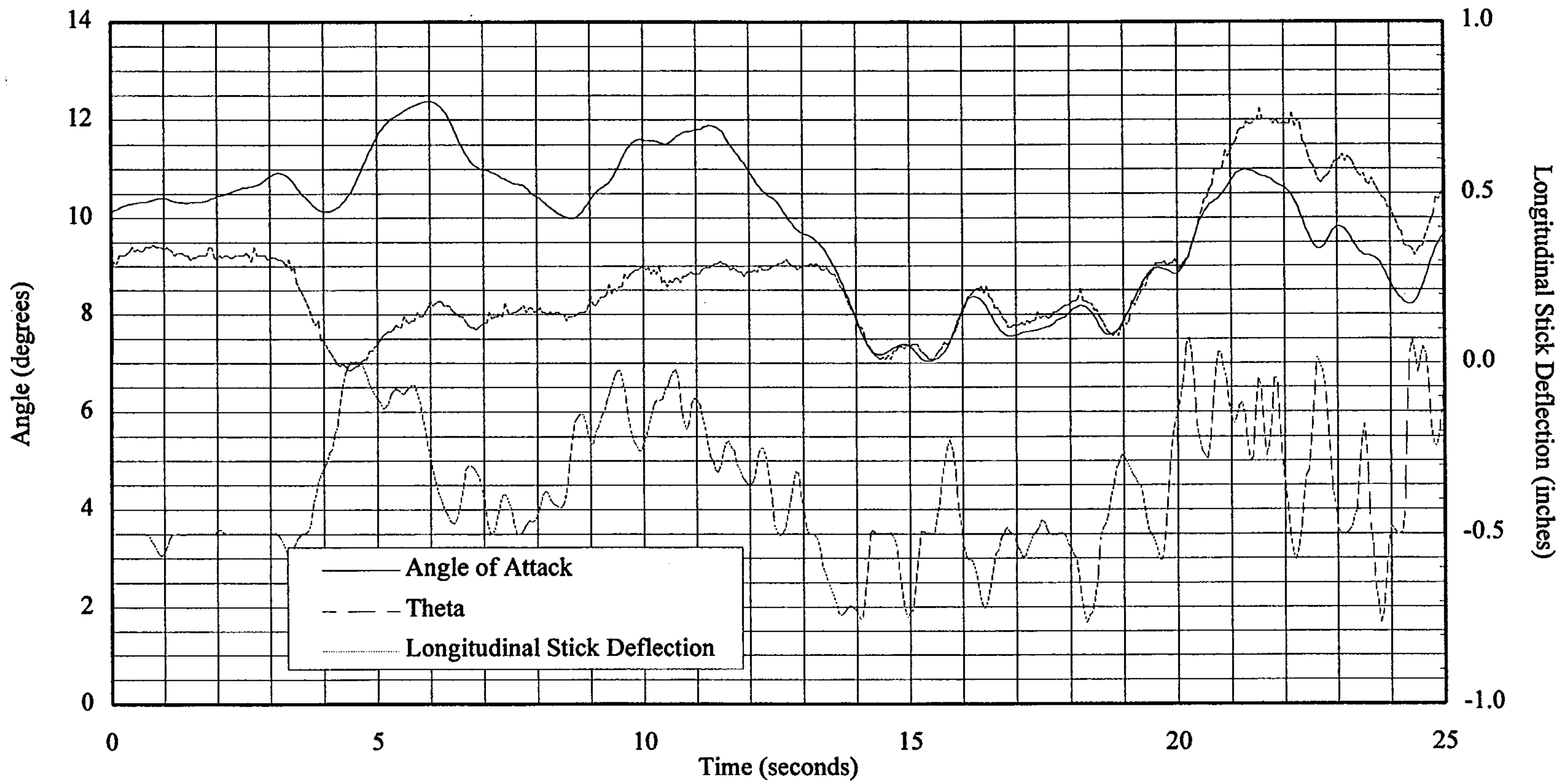

Figure J56 VSS Configuration G Time History of Theta and Longitudinal Stick Deflection

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 88°F
Pressure Altitude: 2,257 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: G - 180
Pilot: 1
Test Point: 8.5
Aircraft Weight: 24,400 pounds

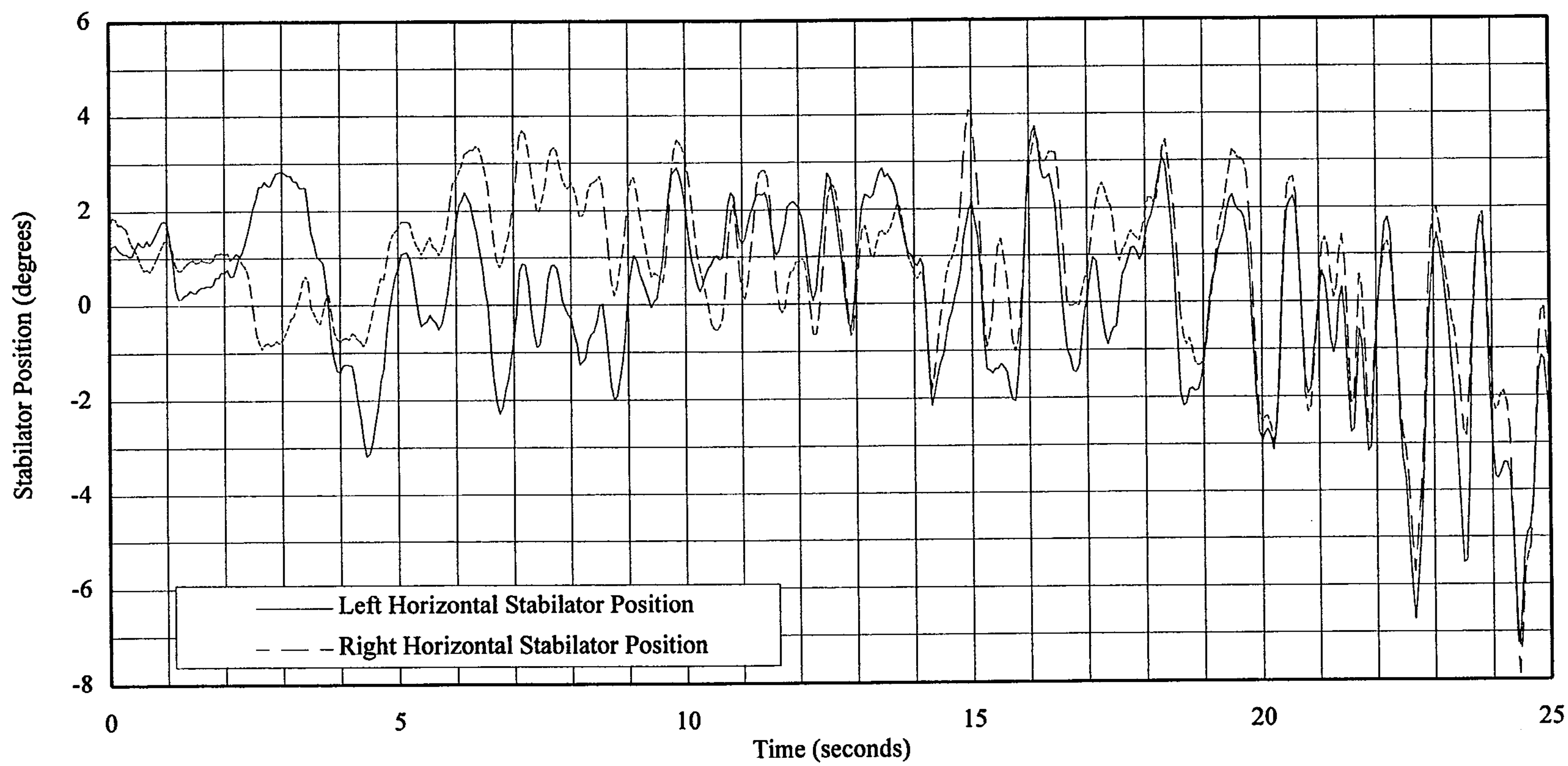

Figure J57 VSS Configuration G Time History of Stabilator Movement

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 88°F
Pressure Altitude: 2,257 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: G - 180
Pilot: 1
Test Point: 8.5
Aircraft Weight: 24,400 pounds

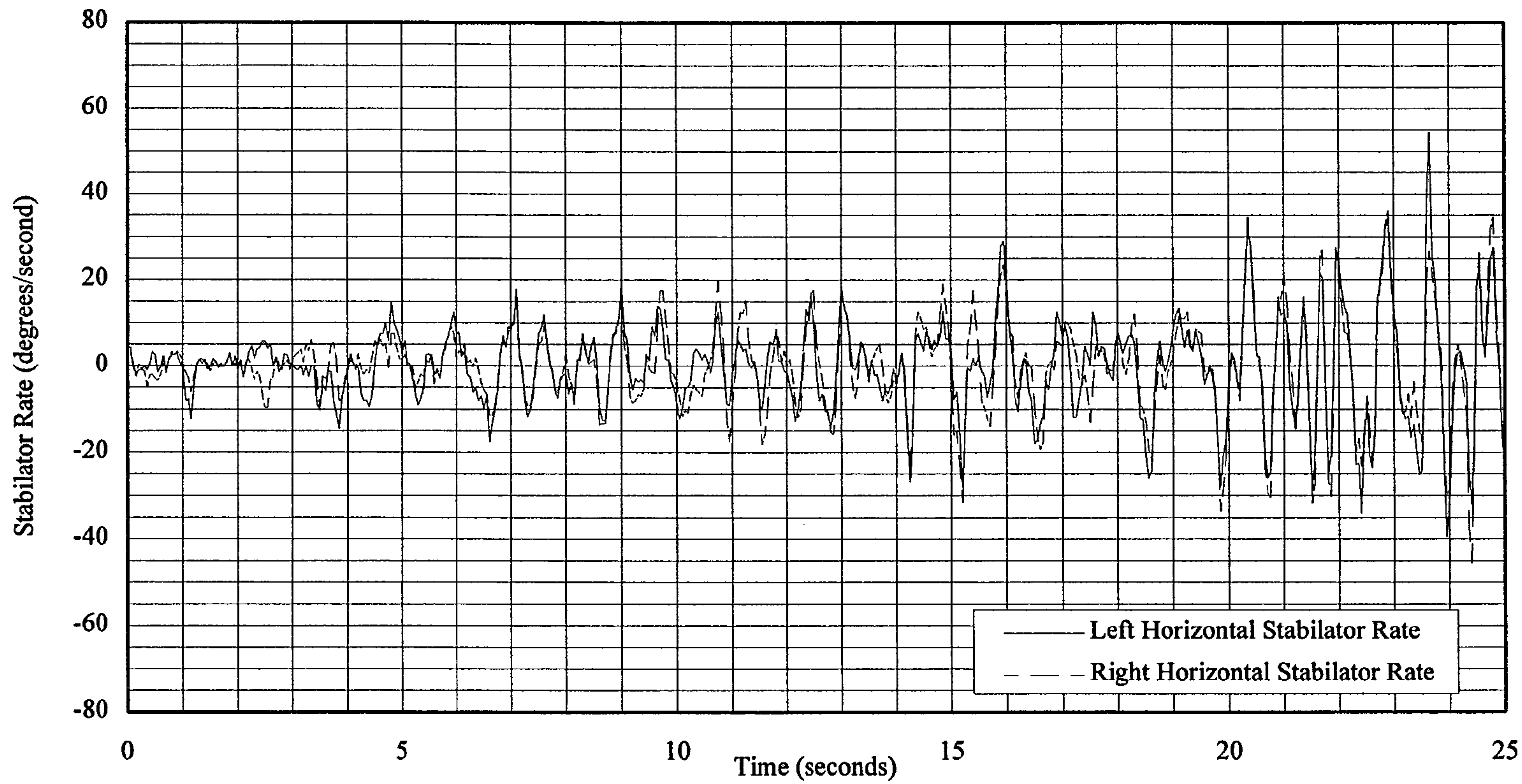

Figure J58 VSS Configuration G Time History of Stabilator Rate

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 88°F
Pressure Altitude: 2,257 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: G - 180
Pilot: 1
Test Point: 8.5
Aircraft Weight: 24,400 pounds

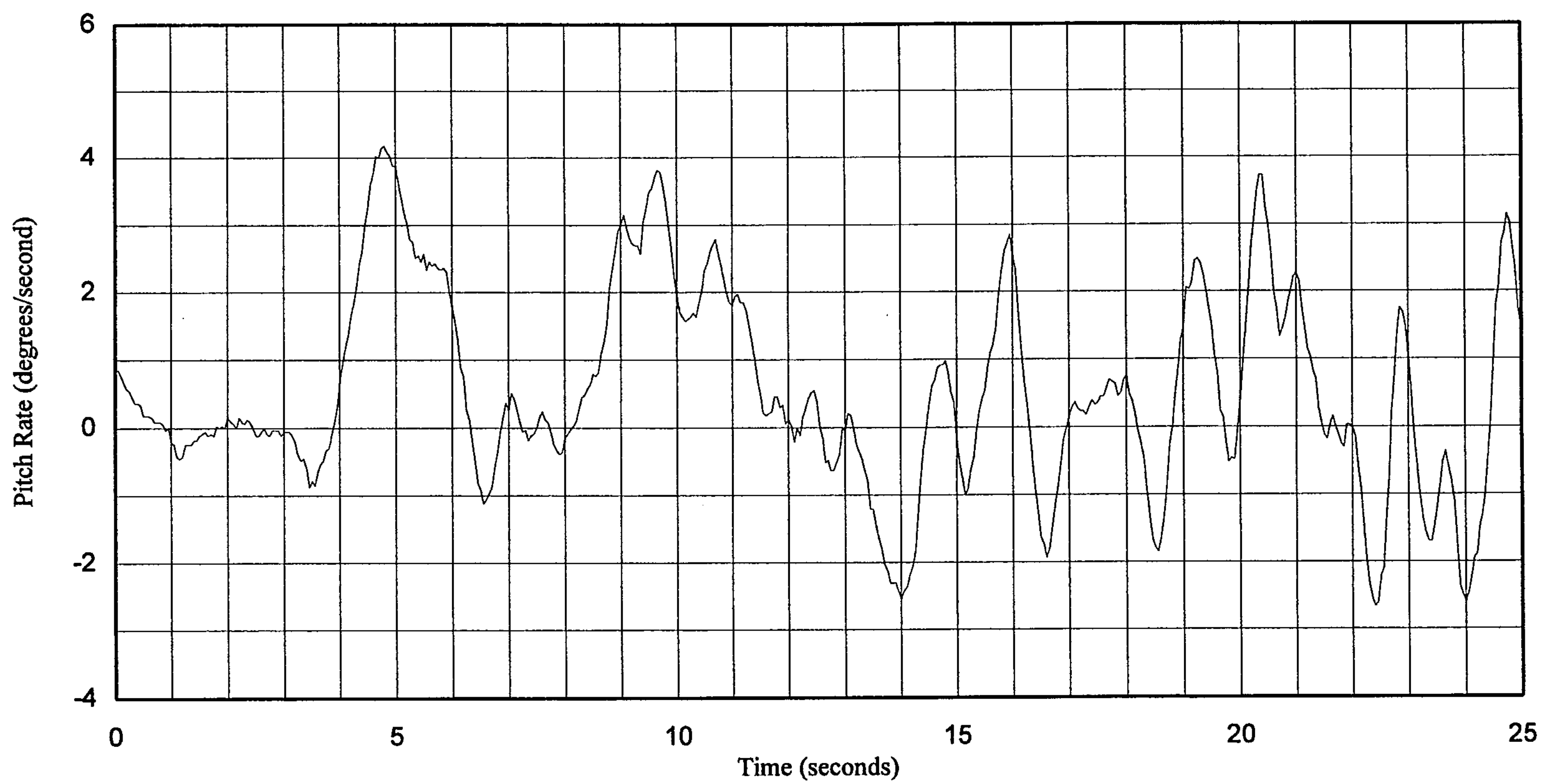

Figure J59 VSS Configuration G Time History of Pitch Rate

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 88°F
Pressure Altitude: 2,257 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: G - 180
Pilot: 1
Test Point: 8.5
Aircraft Weight: 24,400 pounds

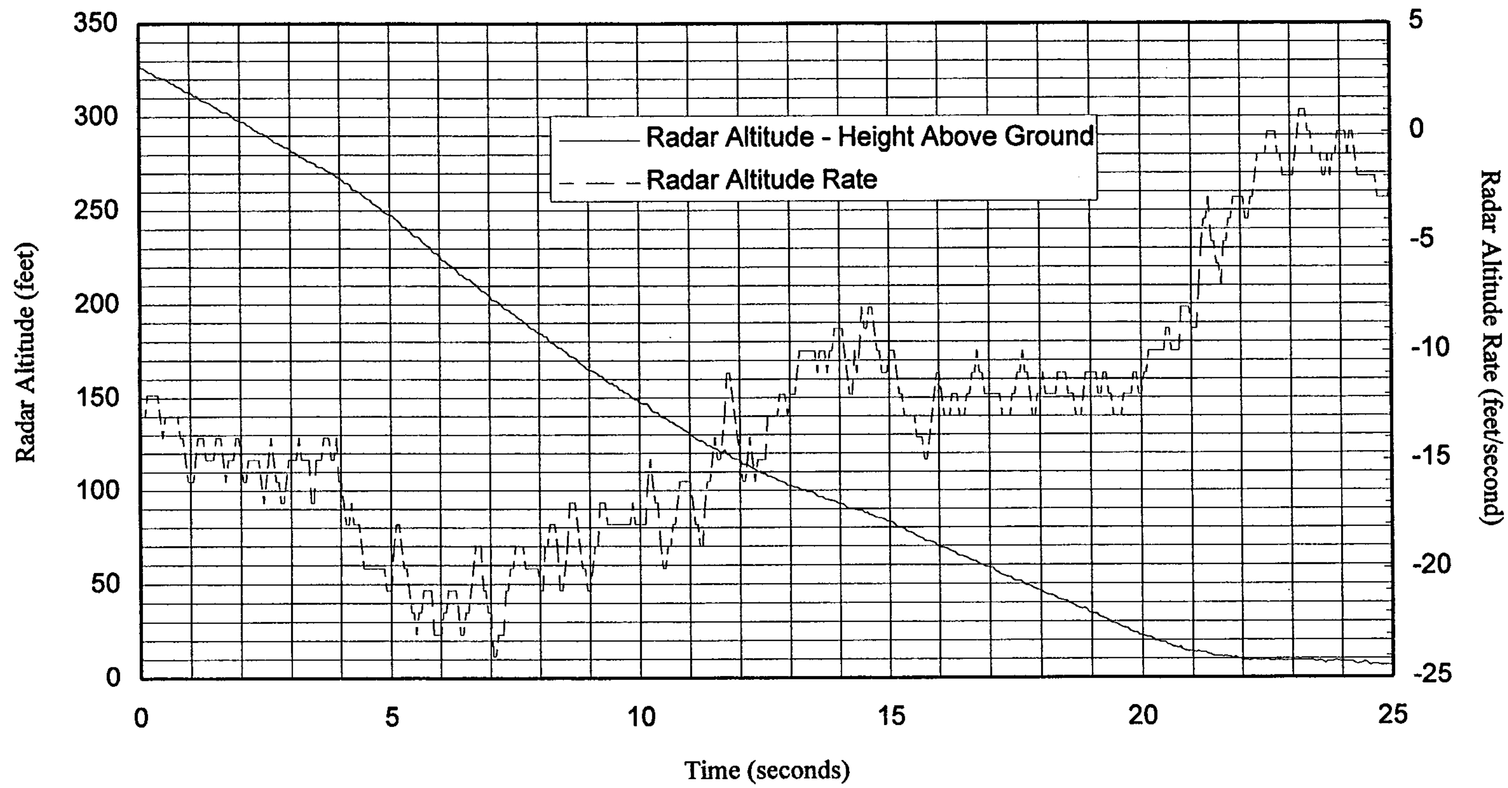

Figure J60 VSS Configuration G Time History of Altitude and Descent Rate

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 88°F
Pressure Altitude: 2,257 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: G - 180
Pilot: 1
Test Point: 8.5
Aircraft Weight: 24,400 pounds

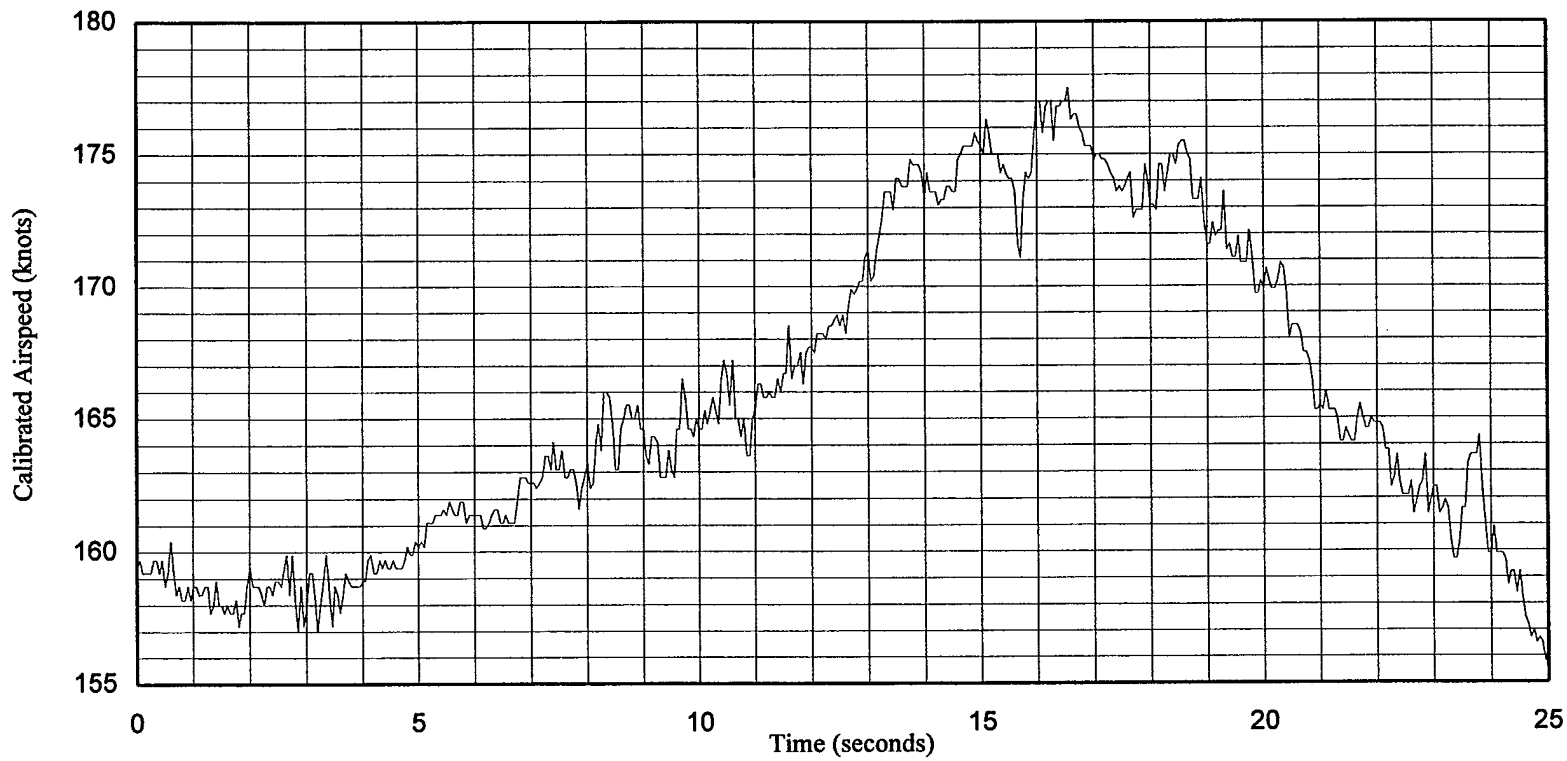

Figure J61 VSS Configuration G Time History of Calibrated Airspeed

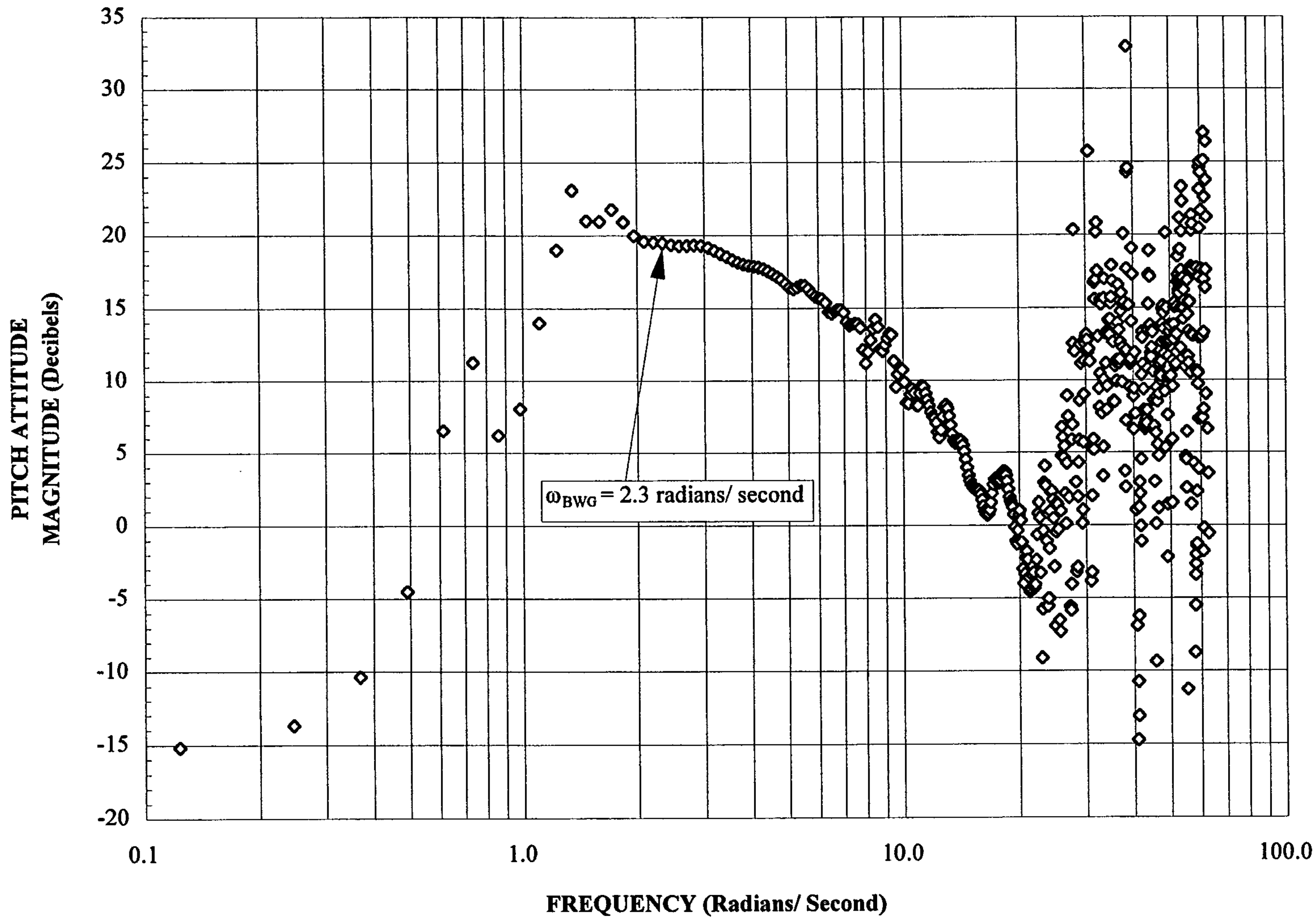

Figure J62 VSS Configuration H Magnitude Bode Plot

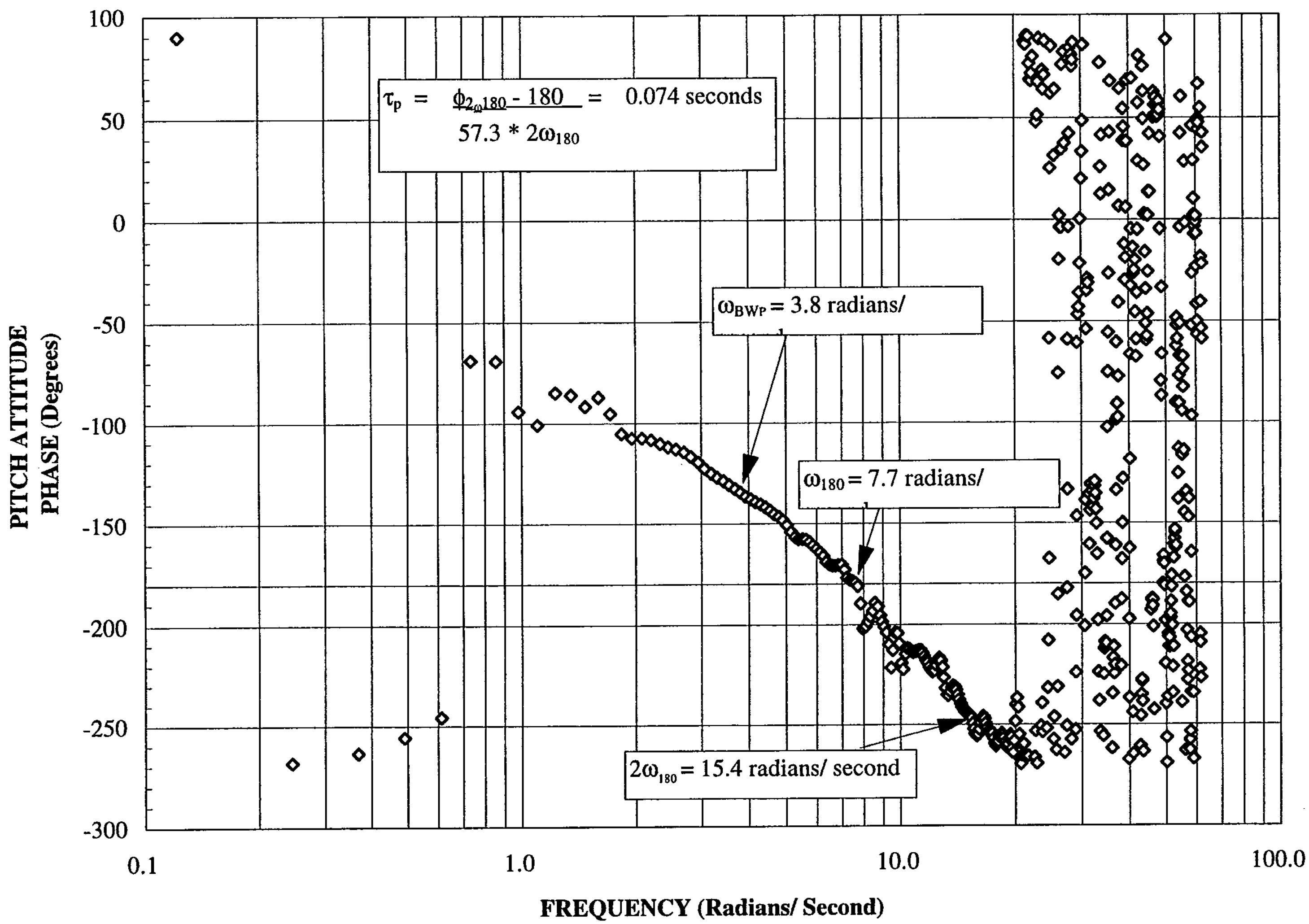

Figure J63 VSS Configuration H Phase Bode Plot

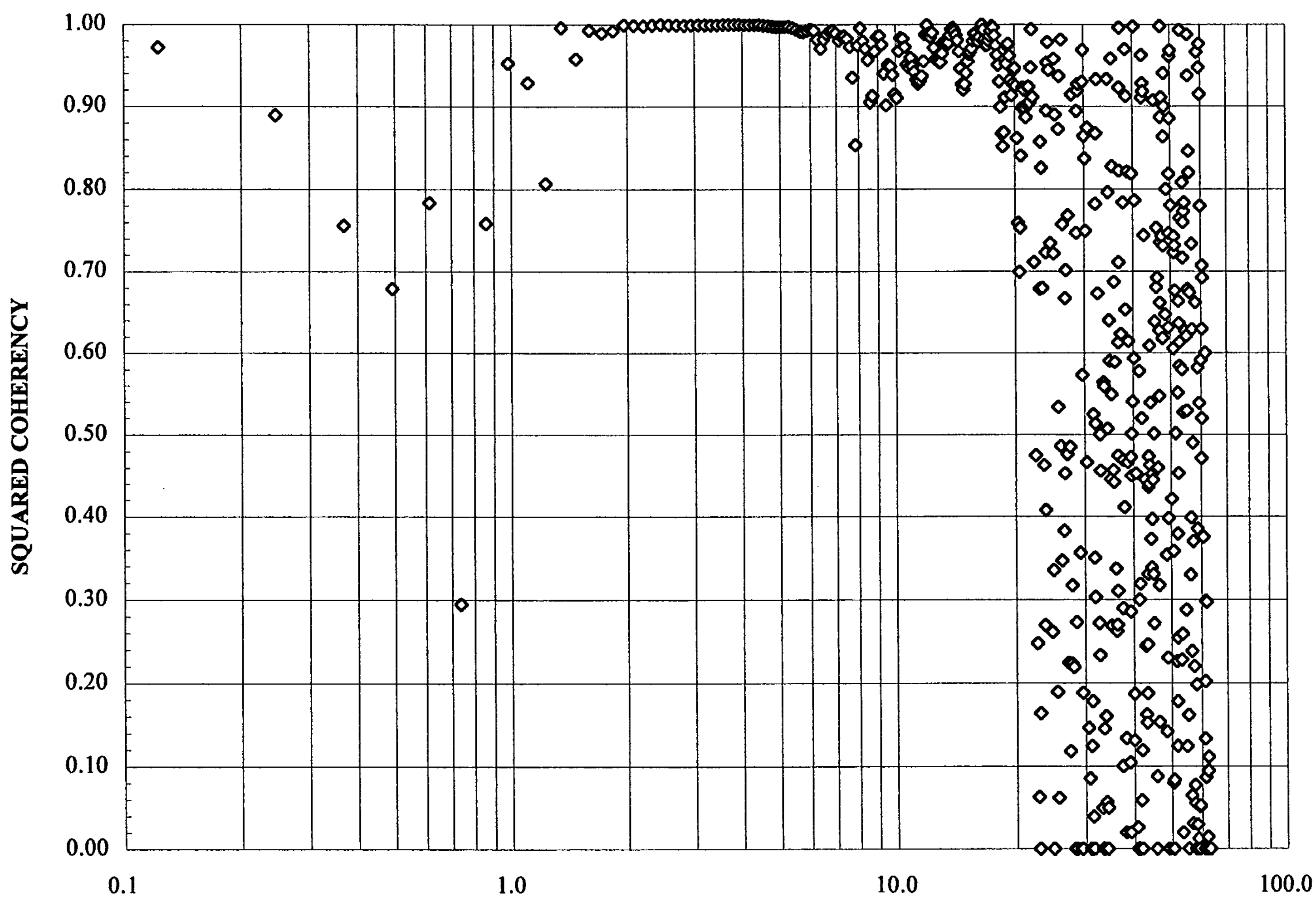

Figure J64 VSS Configuration H Bode Squared Coherency Plot

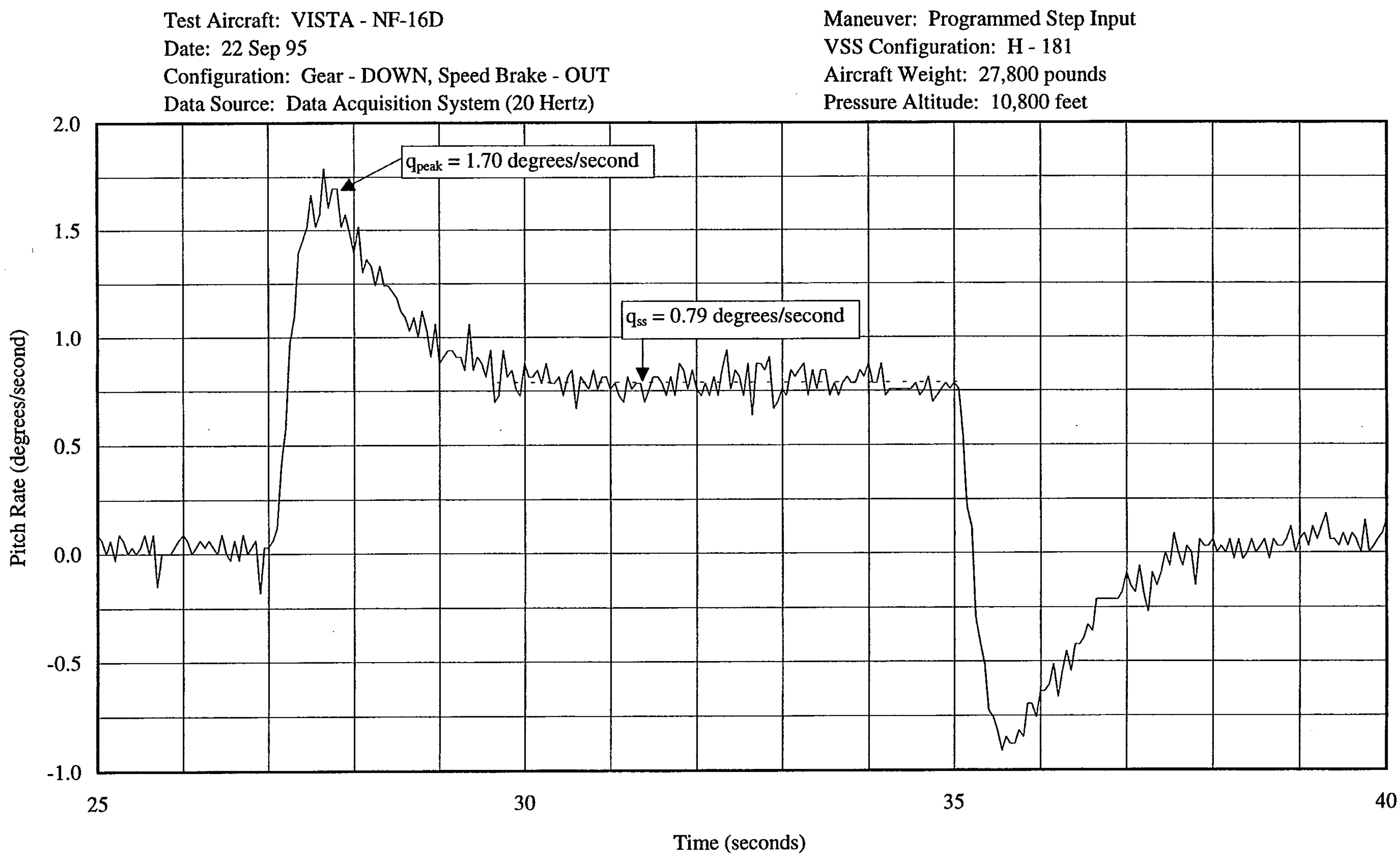

Figure J65 VSS Configuration H Pitch Rate Dropback

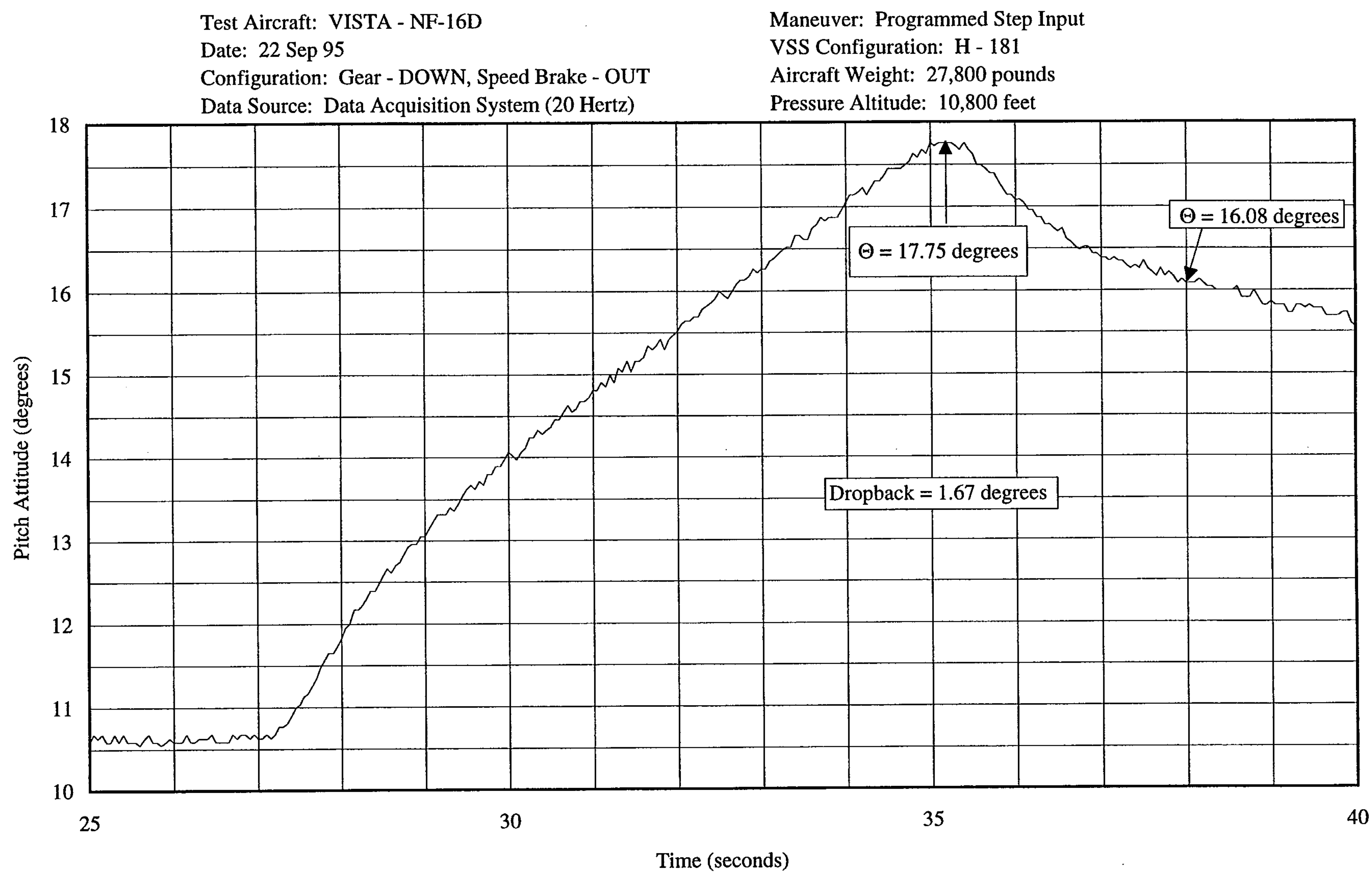

Figure J66 VSS Configuration H Pitch Angle Dropback

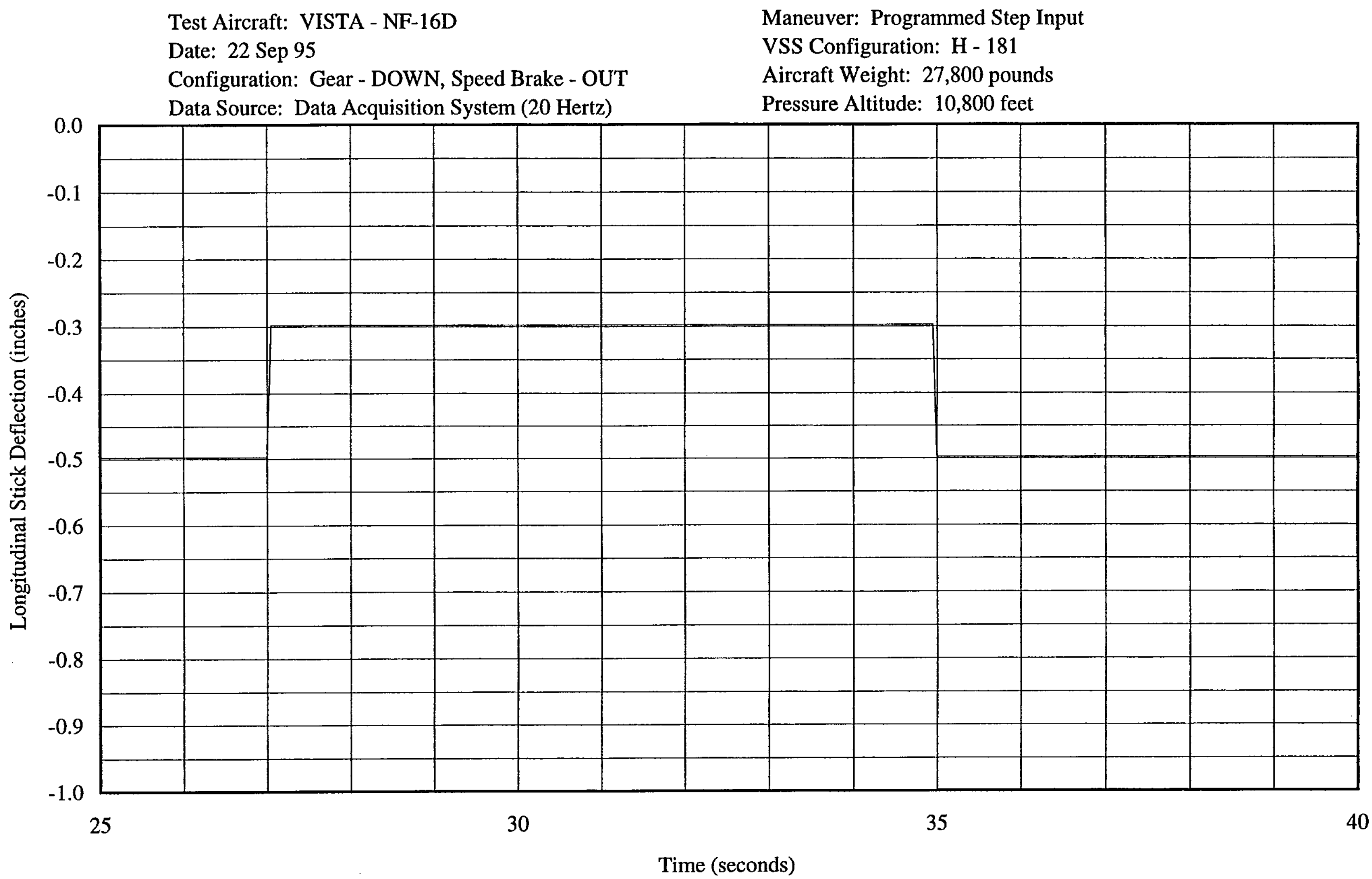

Figure J67 VSS Configuration H Pitch Input Dropback

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: H - 181
Pilot: 2
Test Point: 3.3
Aircraft Weight: 26,300 pounds

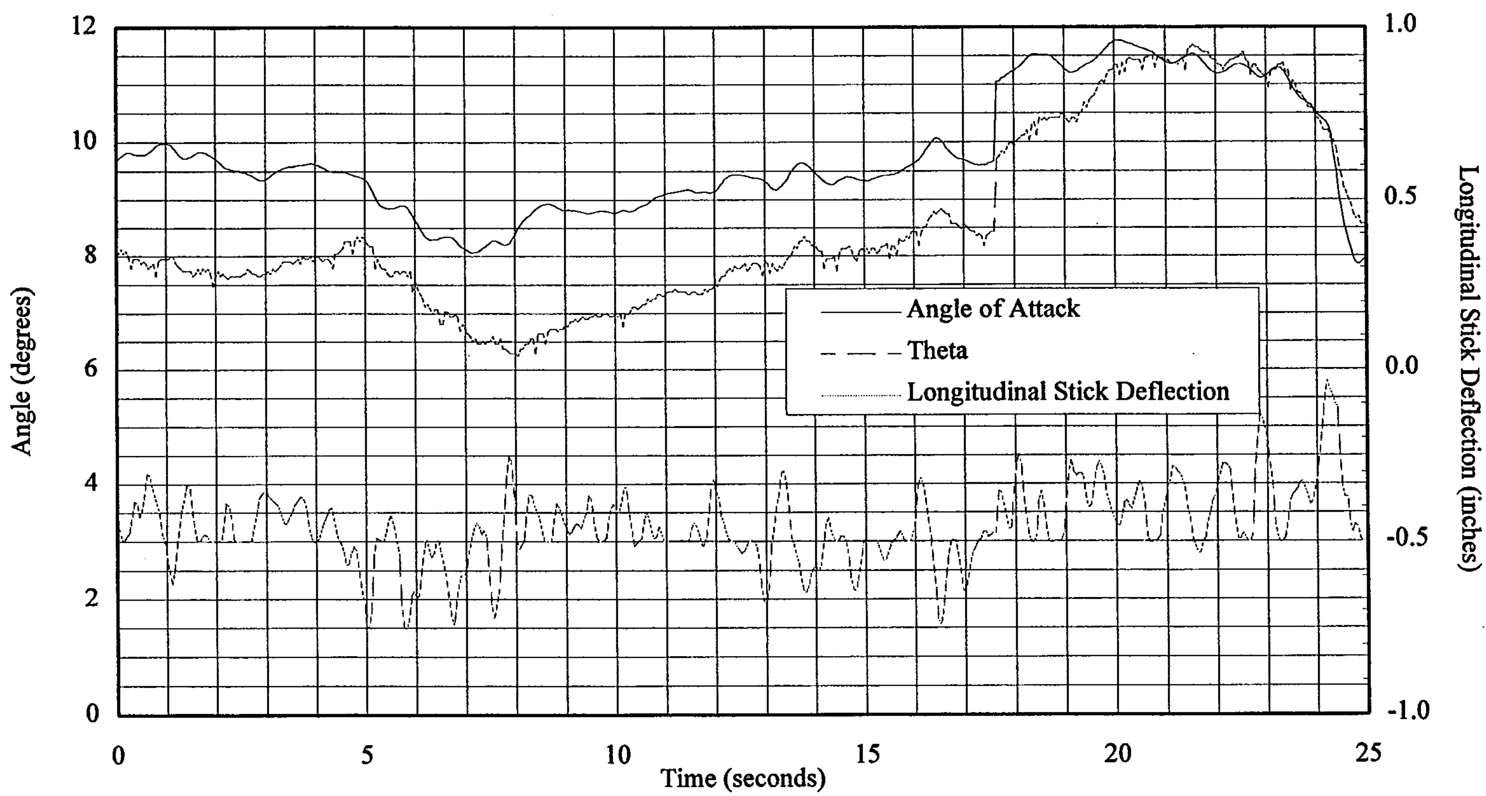

Figure J68 VSS Configuration H Time History of Theta and Longitudinal Stick Deflection

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: H - 181
Pilot: 2
Test Point: 3.3
Aircraft Weight: 26,300 pounds

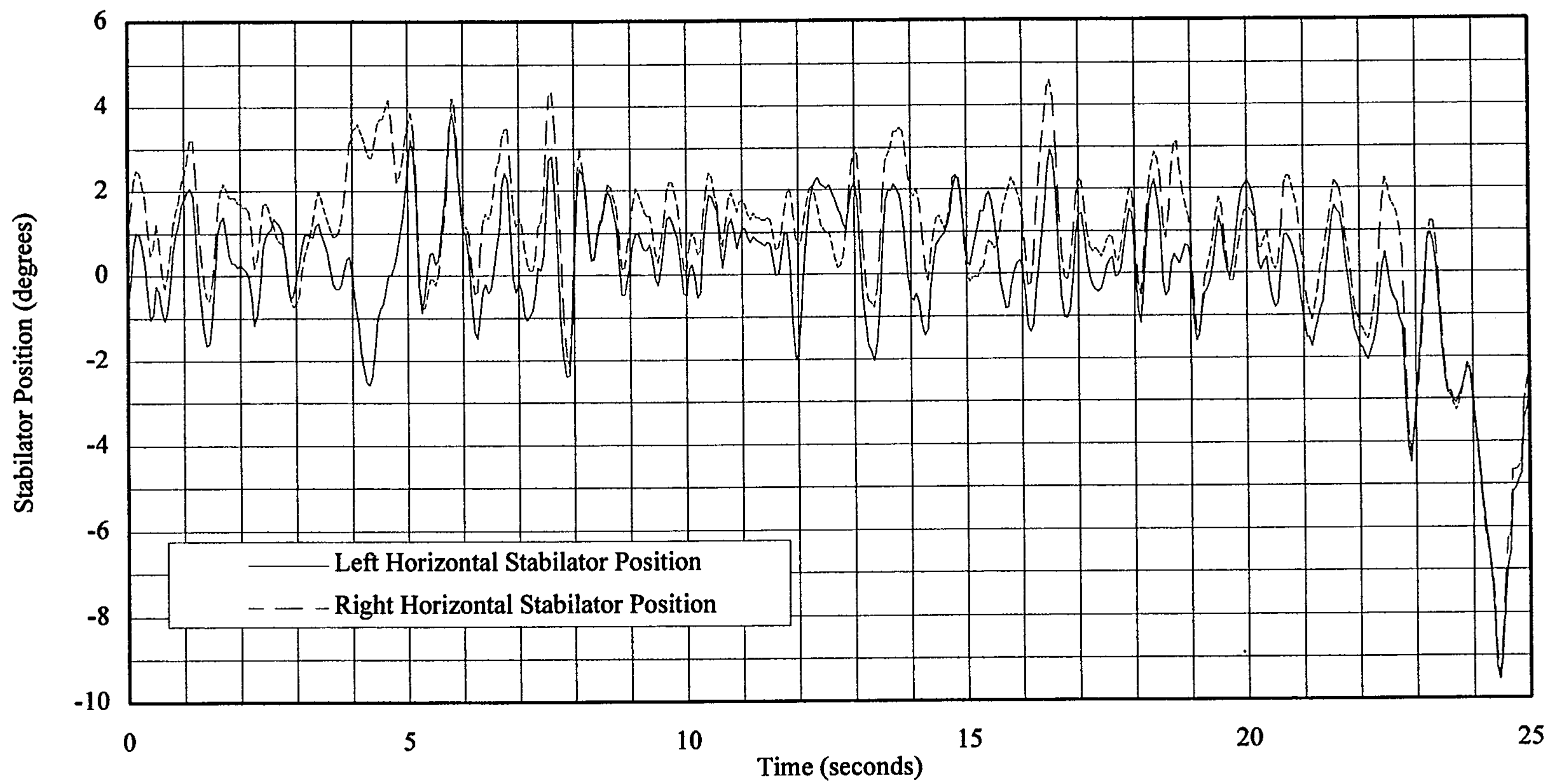

Figure J69 VSS Configuration H Time History of Stabilator Movement

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: H - 181
Pilot: 2
Test Point: 3.3
Aircraft Weight: 26,300 pounds

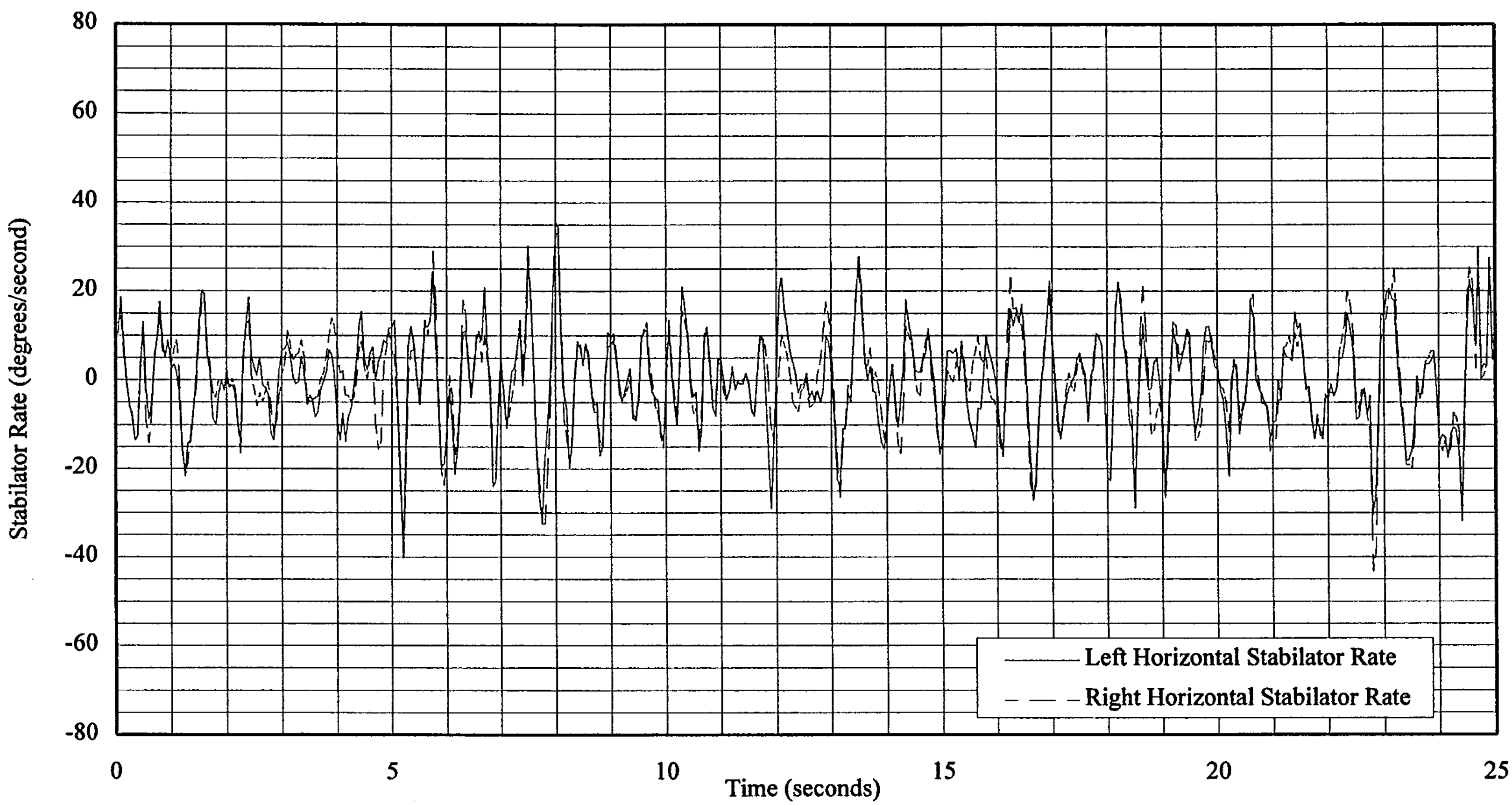

Figure J70 VSS Configuration H Time History of Stabilator Rate

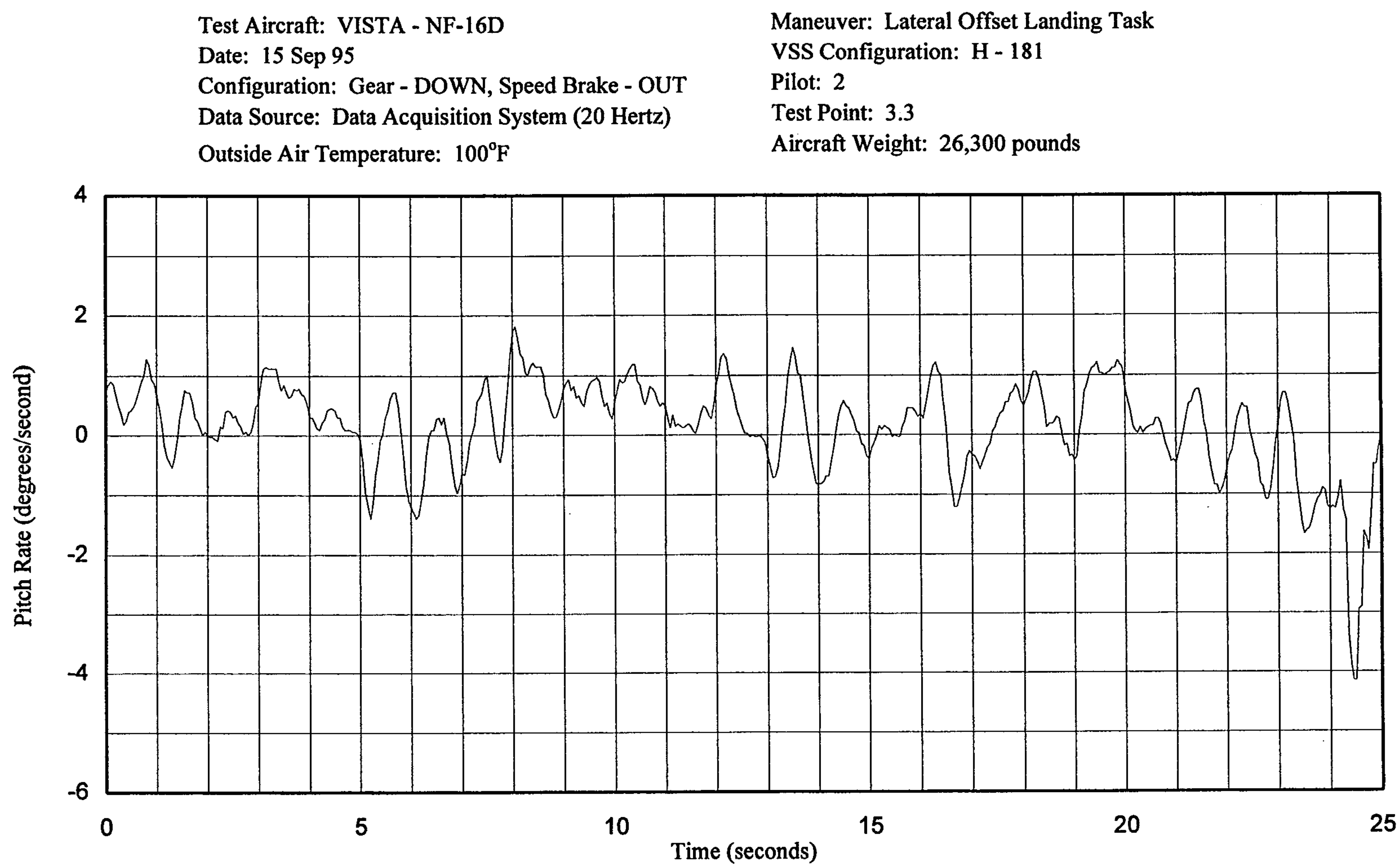

Figure J71 VSS Configuration H Time History of Pitch Rate

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: H - 181
Pilot: 2
Test Point: 3.3
Aircraft Weight: 26,300 pounds

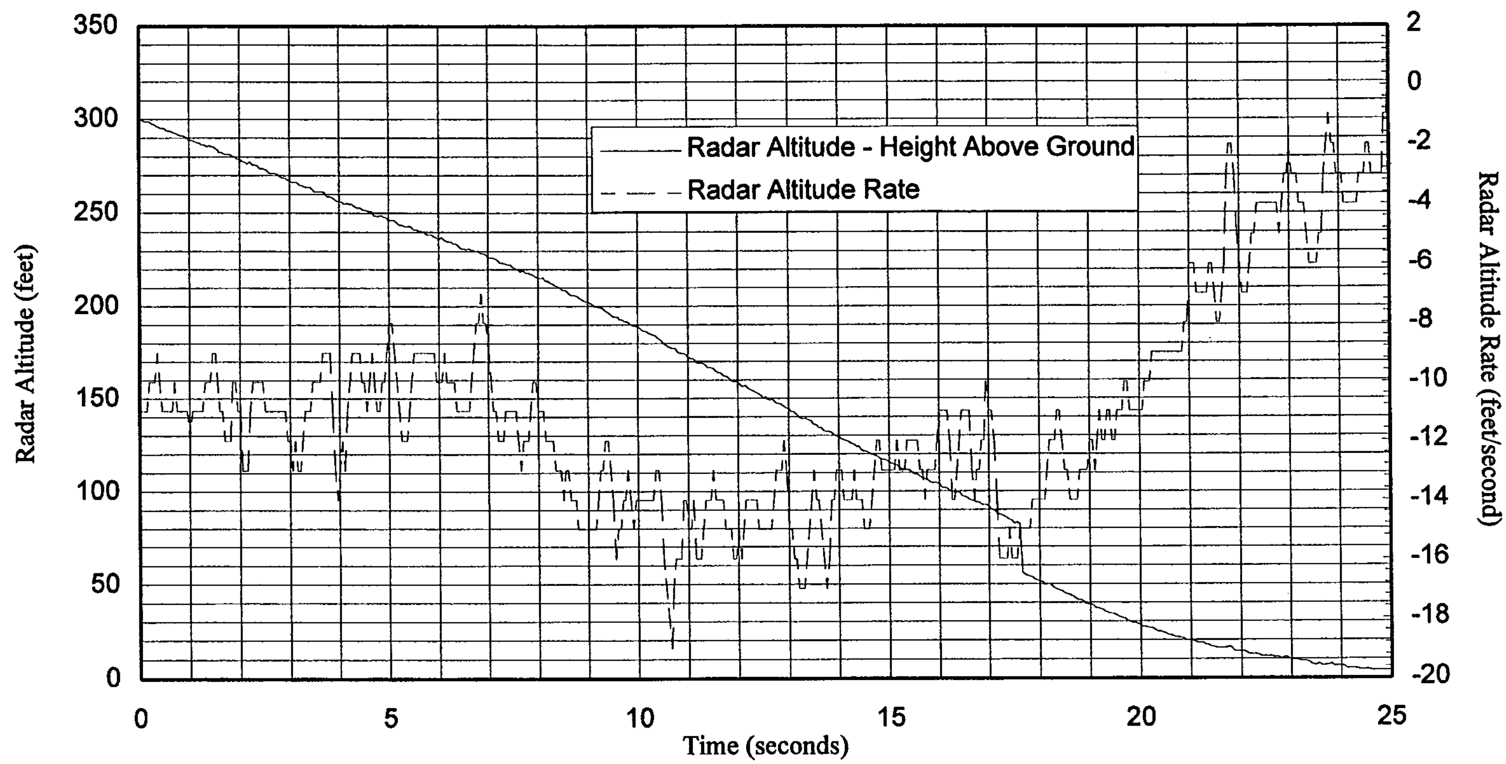

Figure J72 VSS Configuration H Time History of Altitude and Descent Rate

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: H - 181
Pilot: 2
Test Point: 3.3
Aircraft Weight: 26,300 pounds

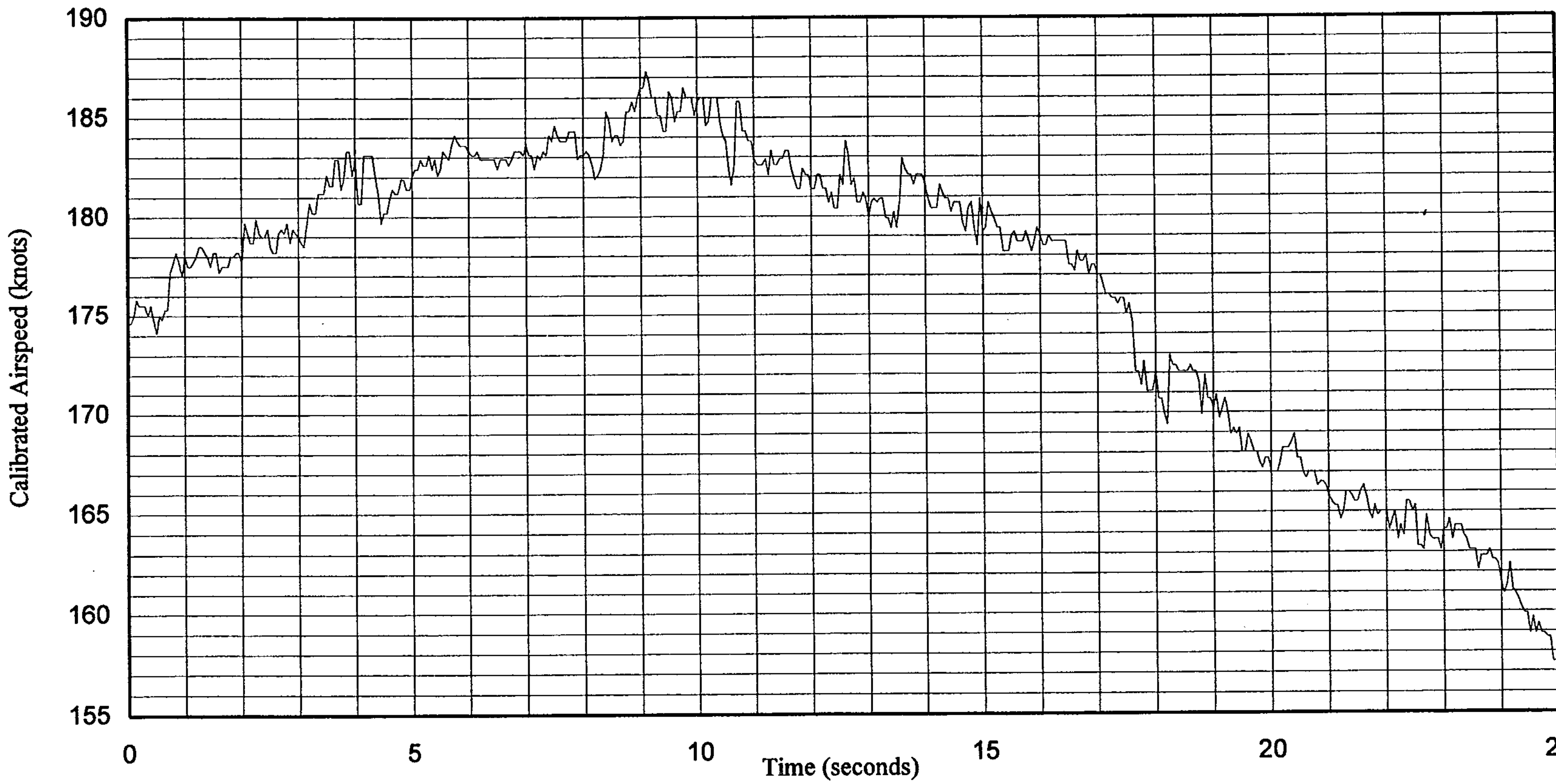

Figure J73 VSS Configuration H Time History of Calibrated Airspeed

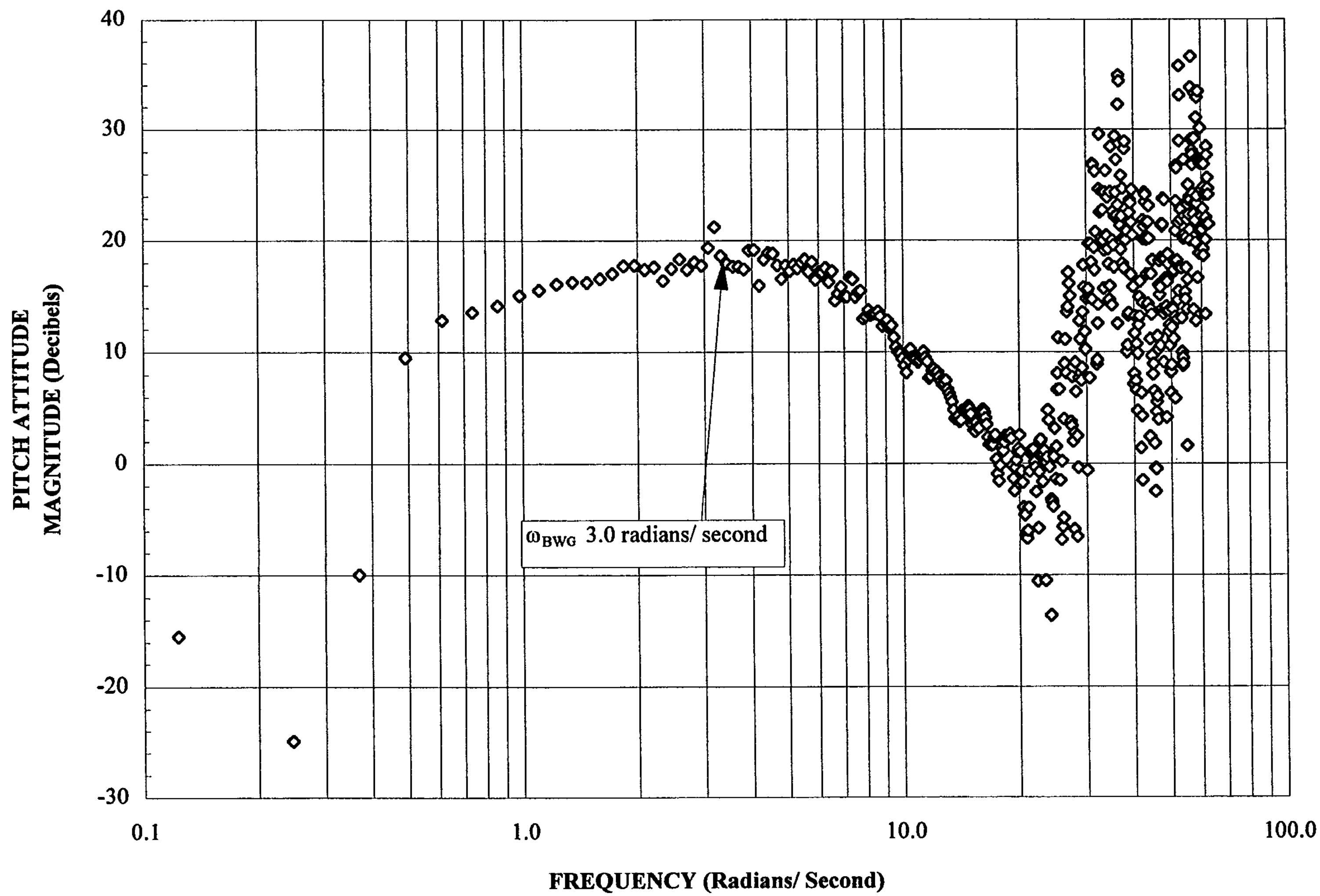

Figure J74 VSS Configuration I Magnitude Bode Plot

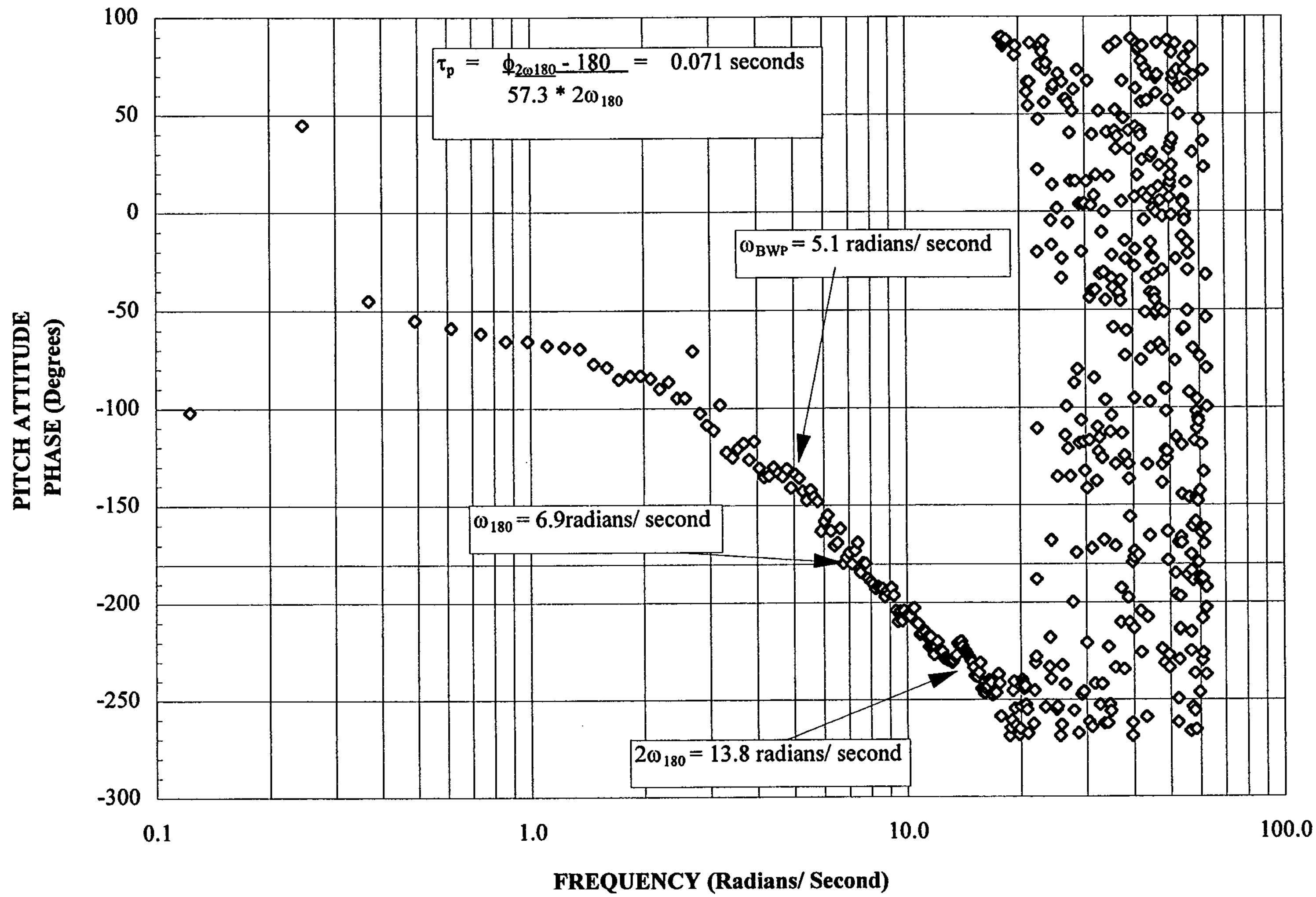

Figure J75 VSS Configuration I Phase Bode Plot

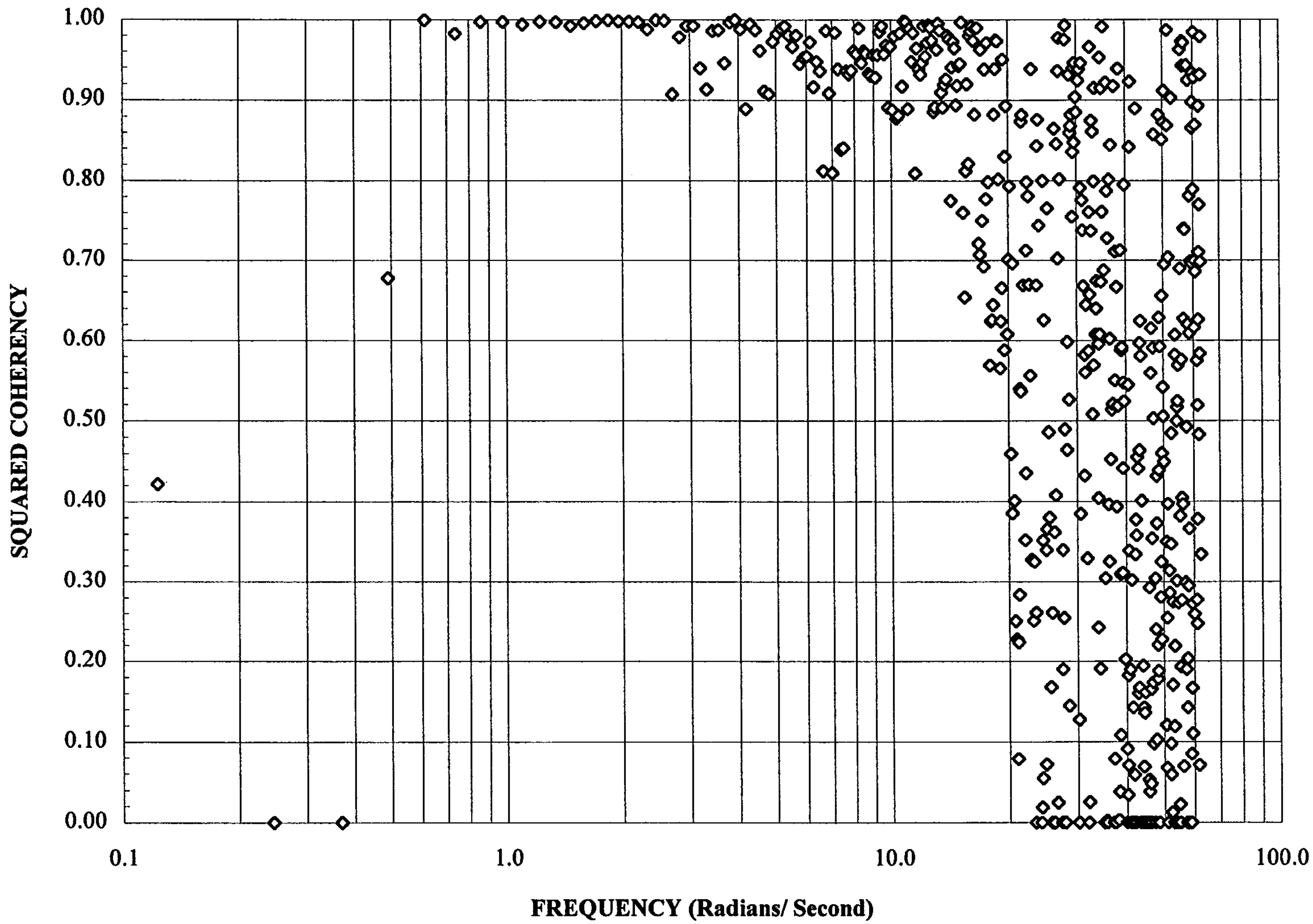

Figure J76 VSS Configuration I Bode Squared Coherency Plot

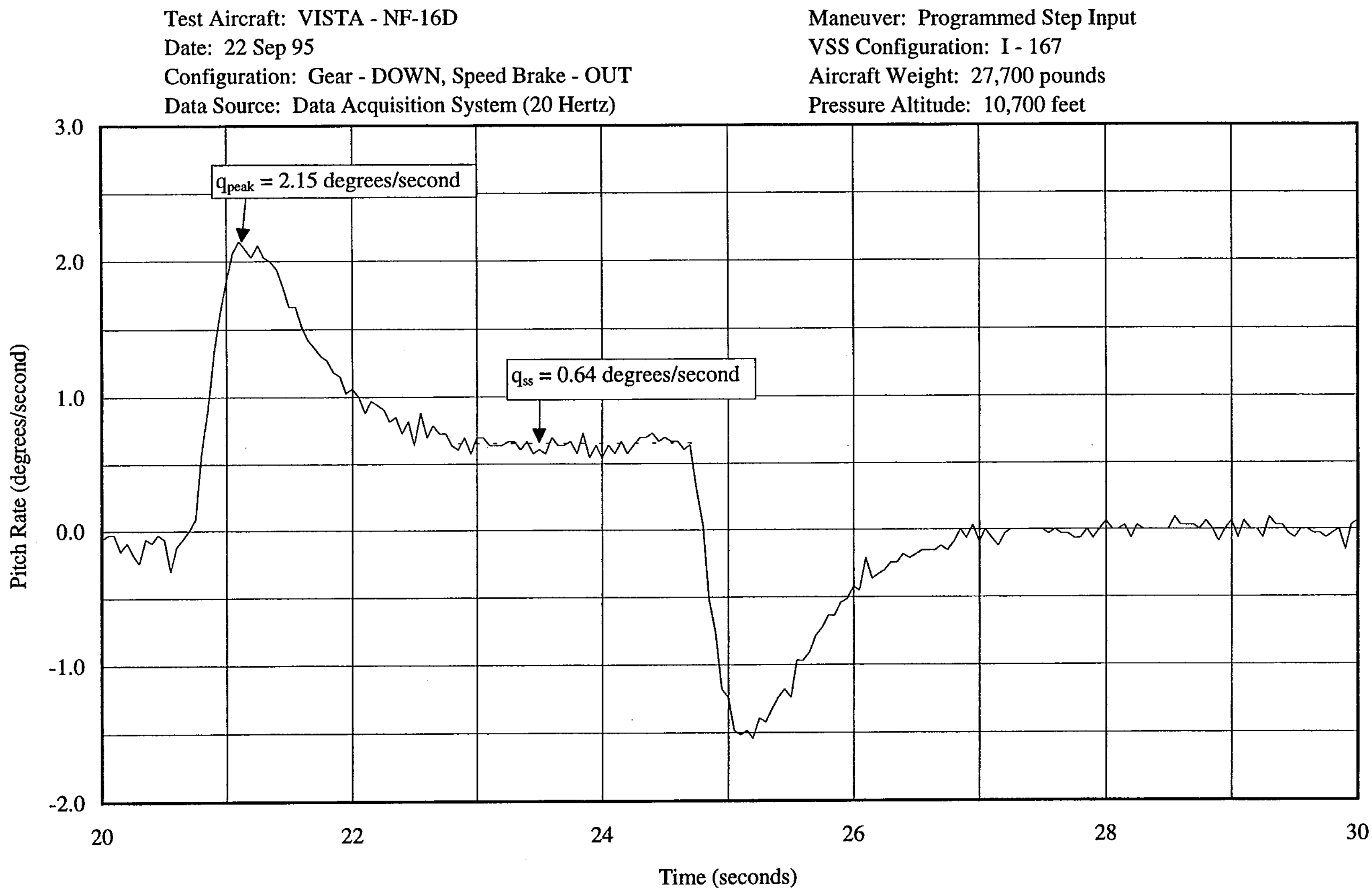

Figure J77 VSS Configuration I Pitch Rate Dropback

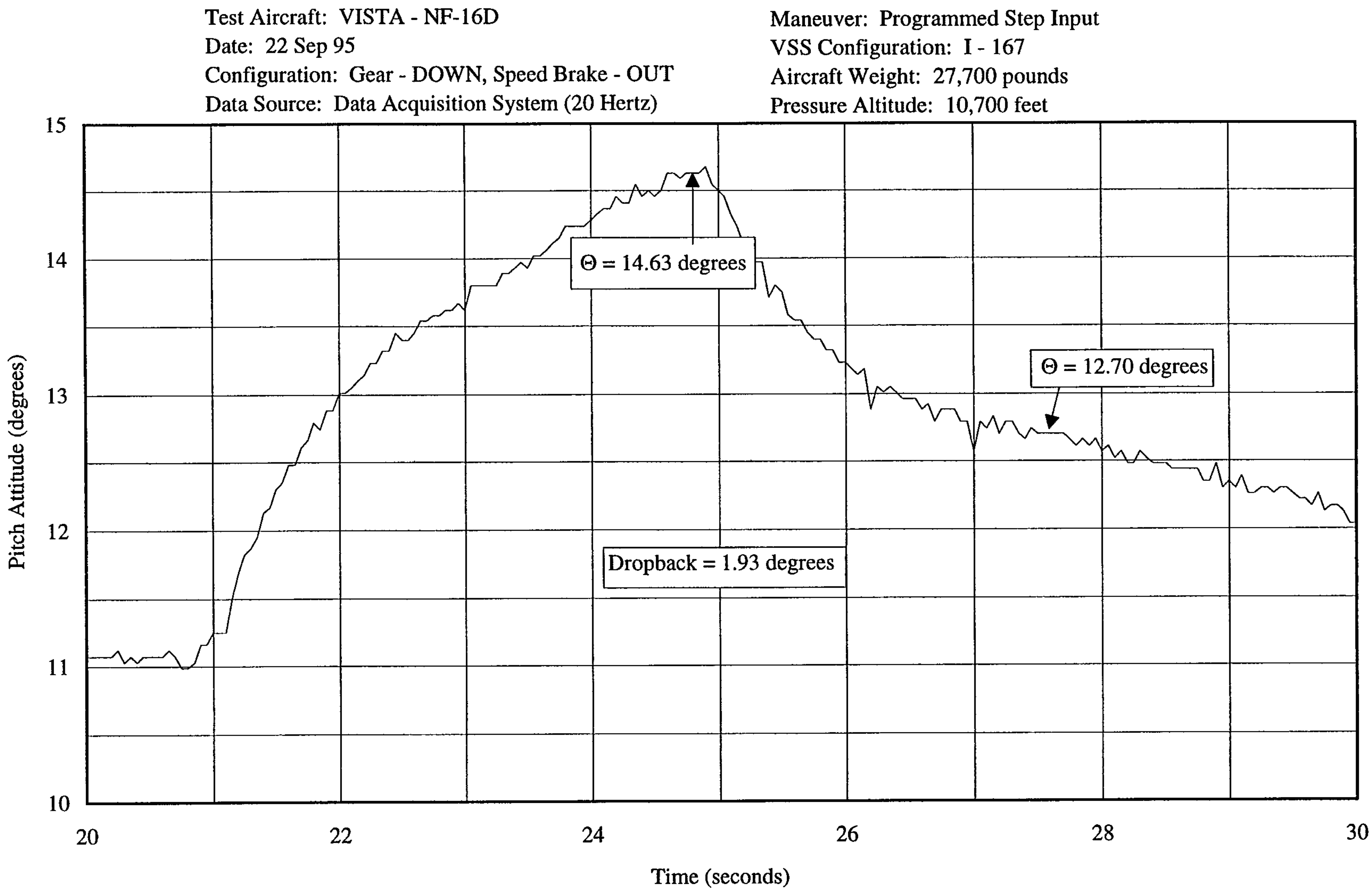

Figure J78 VSS Configuration I Pitch Angle Dropback

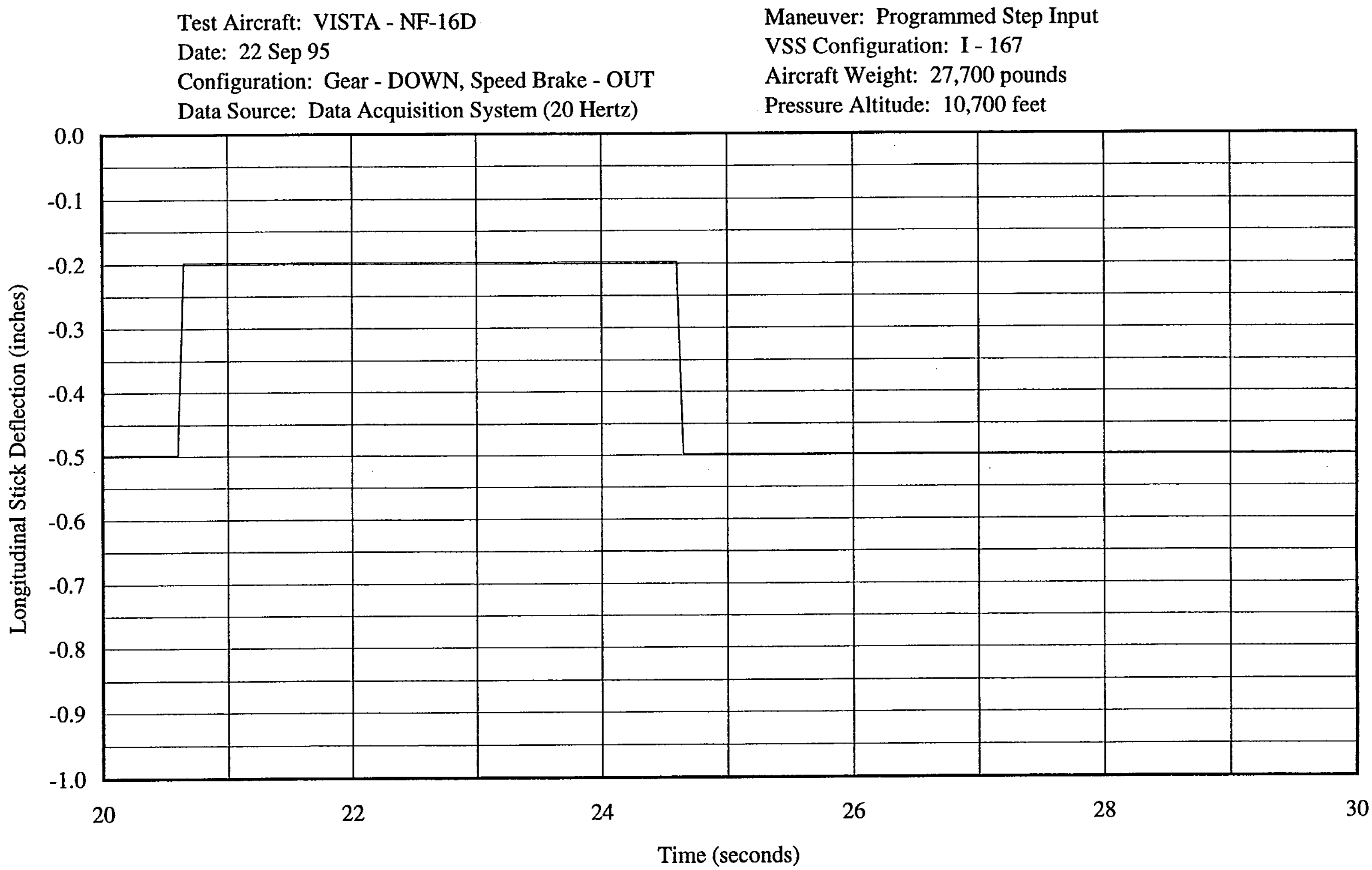

Figure J79 VSS Configuration I Pitch Input Dropback

Test Aircraft: VISTA - NF-16D
Date: 17 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 94°F
Pressure Altitude: 2,275 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: I - 167
Pilot: 2
Test Point: 7.5
Aircraft Weight: 25,100 pounds

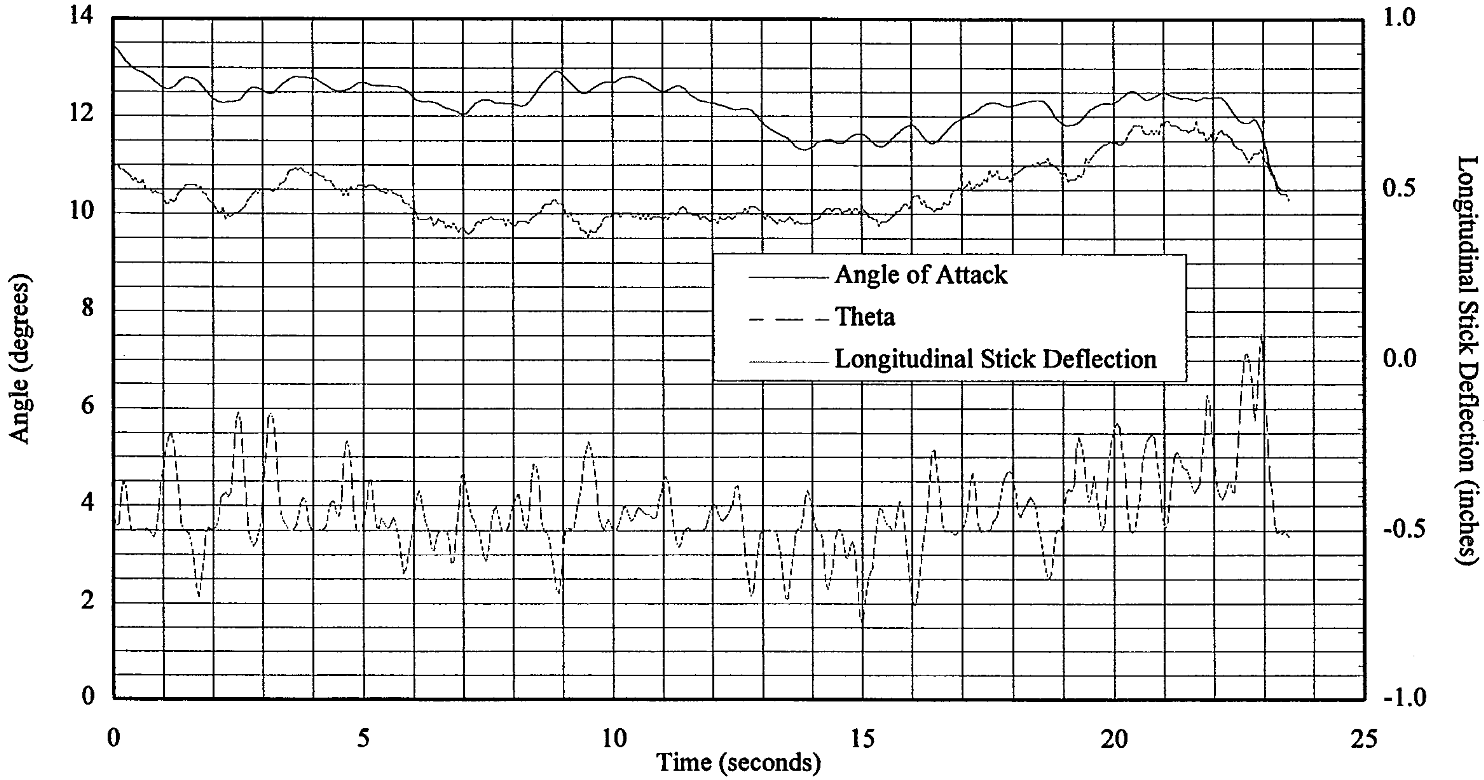

Figure J80 VSS Configuration I Time History of Theta and Longitudinal Stick Deflection

Test Aircraft: VISTA - NF-16D
Date: 17 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 94°F
Pressure Altitude: 2,275 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: I - 167
Pilot: 2
Test Point: 7.5
Aircraft Weight: 25,100 pounds

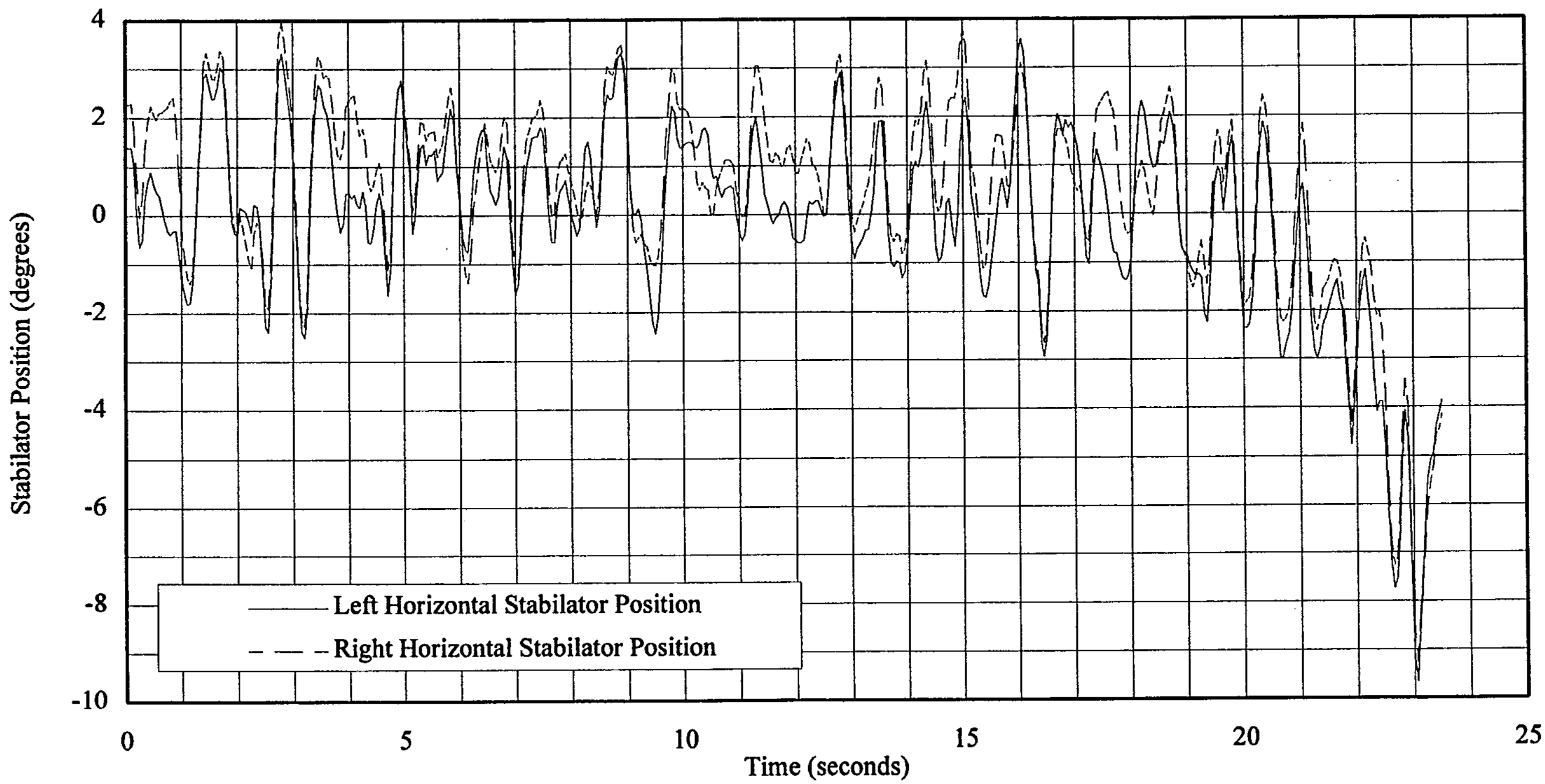

Figure J81 VSS Configuration I Time History of Stabilator Movement

Test Aircraft: VISTA - NF-16D
Date: 17 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 94°F
Pressure Altitude: 2,275 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: I - 167
Pilot: 2
Test Point: 7.5
Aircraft Weight: 25,100 pounds

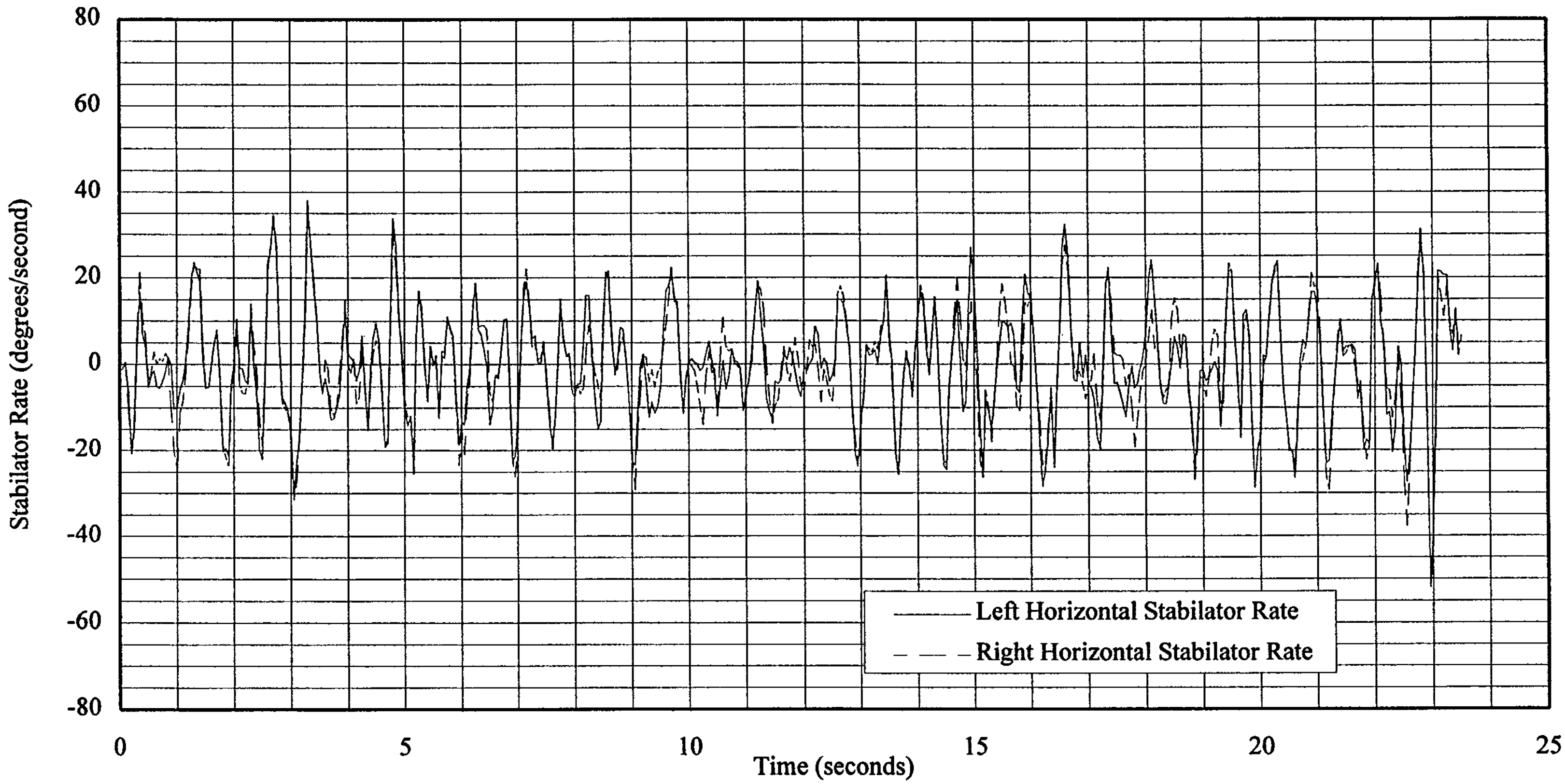

Figure J82 VSS Configuration I Time History of Stabilator Rate

Test Aircraft: VISTA - NF-16D
Date: 17 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 94°F
Pressure Altitude: 2,275 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: I - 167
Pilot: 2
Test Point: 7.5
Aircraft Weight: 25,100 pounds

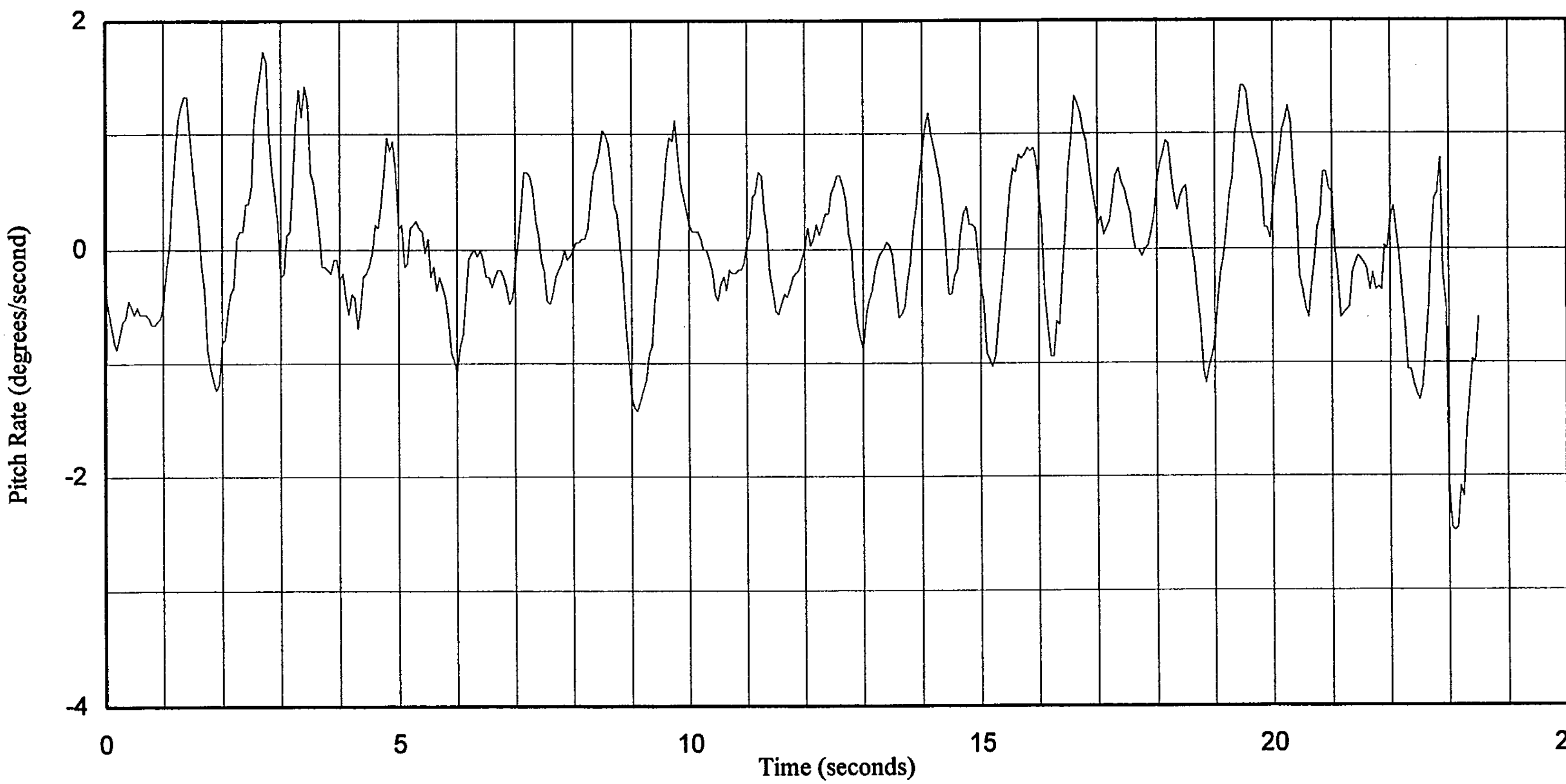

Figure J83 VSS Configuration I Time History of Pitch Rate

Test Aircraft: VISTA - NF-16D
Date: 17 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 94°F
Pressure Altitude: 2,275 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: I - 167
Pilot: 2
Test Point: 7.5
Aircraft Weight: 25,100 pounds

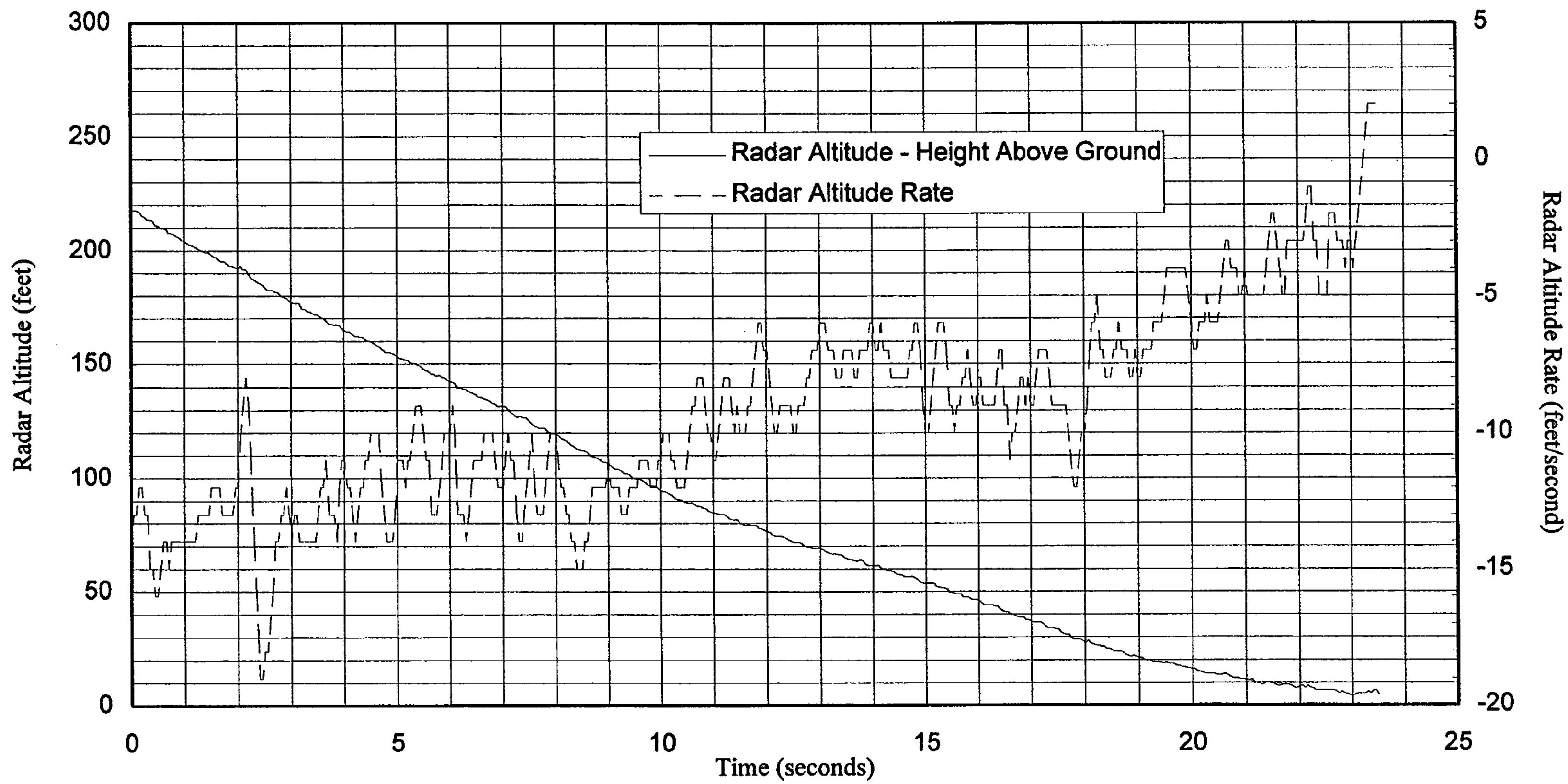

Figure J84 VSS Configuration I Time History of Altitude and Descent Rate

Test Aircraft: VISTA - NF-16D
Date: 17 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 94°F
Pressure Altitude: 2,275 feet

Maneuver: Lateral Offset Landing Task
VSS Configuration: I - 167
Pilot: 2
Test Point: 7.5
Aircraft Weight: 25,100 pounds

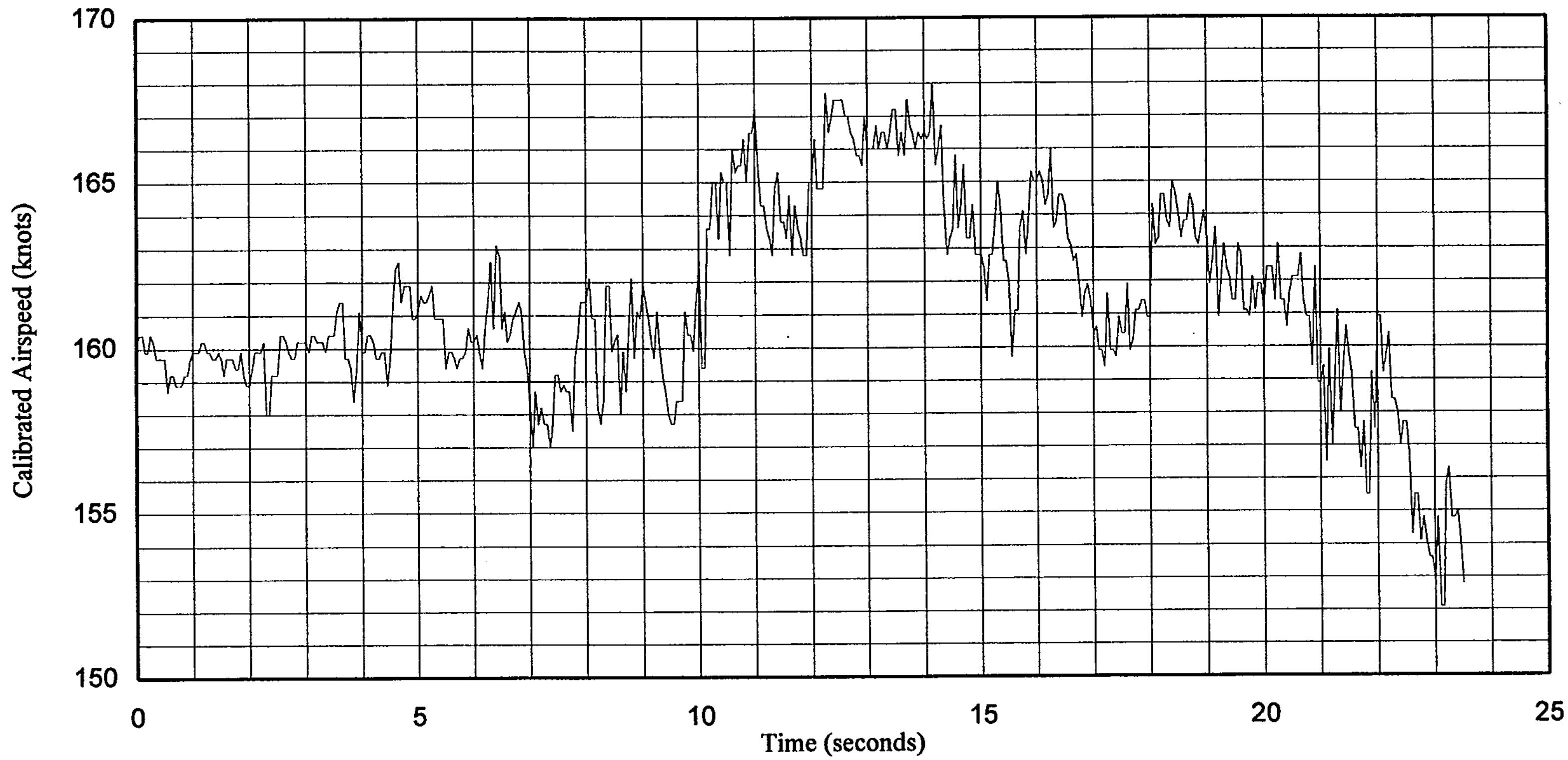

Figure J85 VSS Configuration I Time History of Calibrated Airspeed

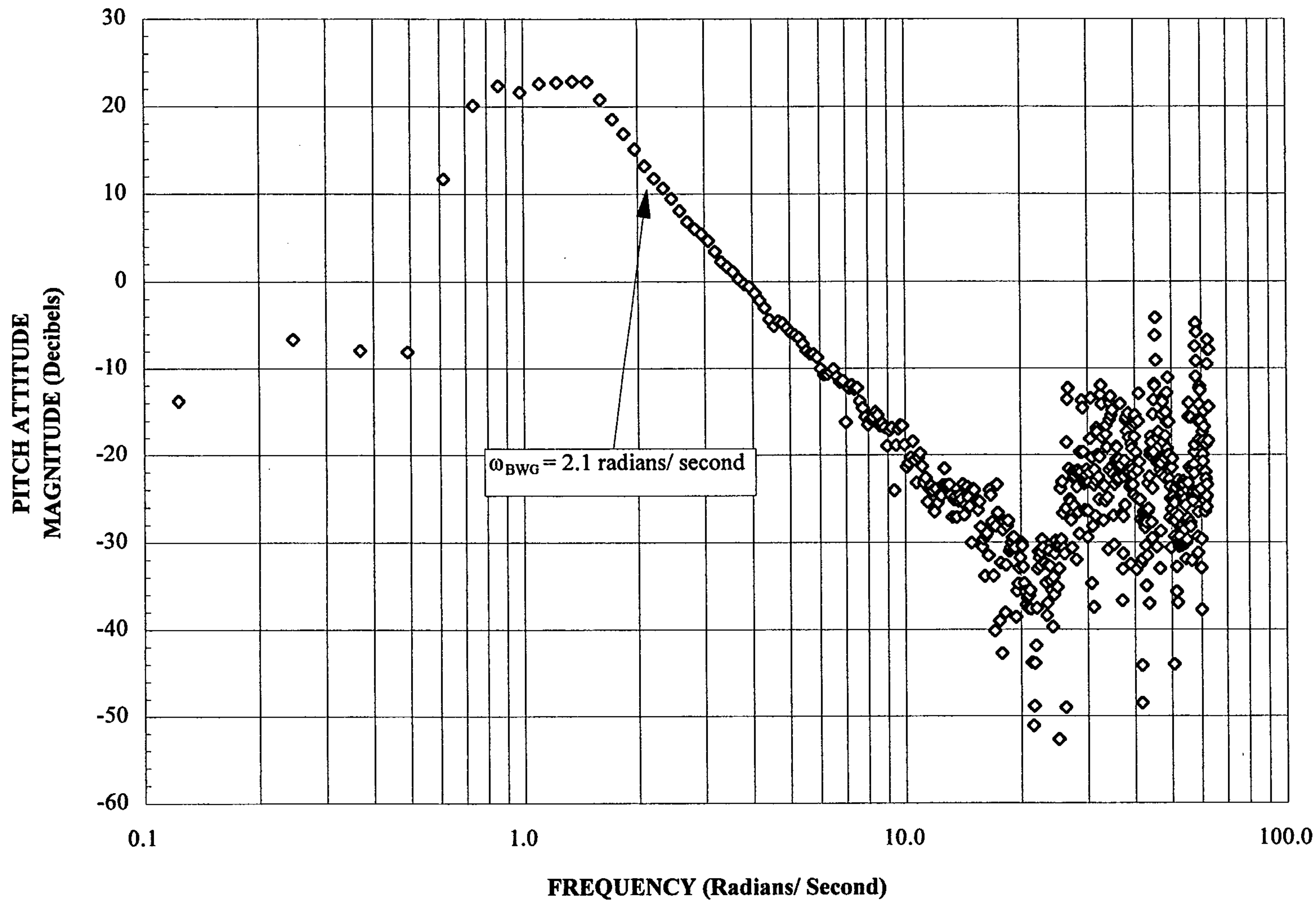

Figure J86 VSS Configuration J Magnitude Bode Plot

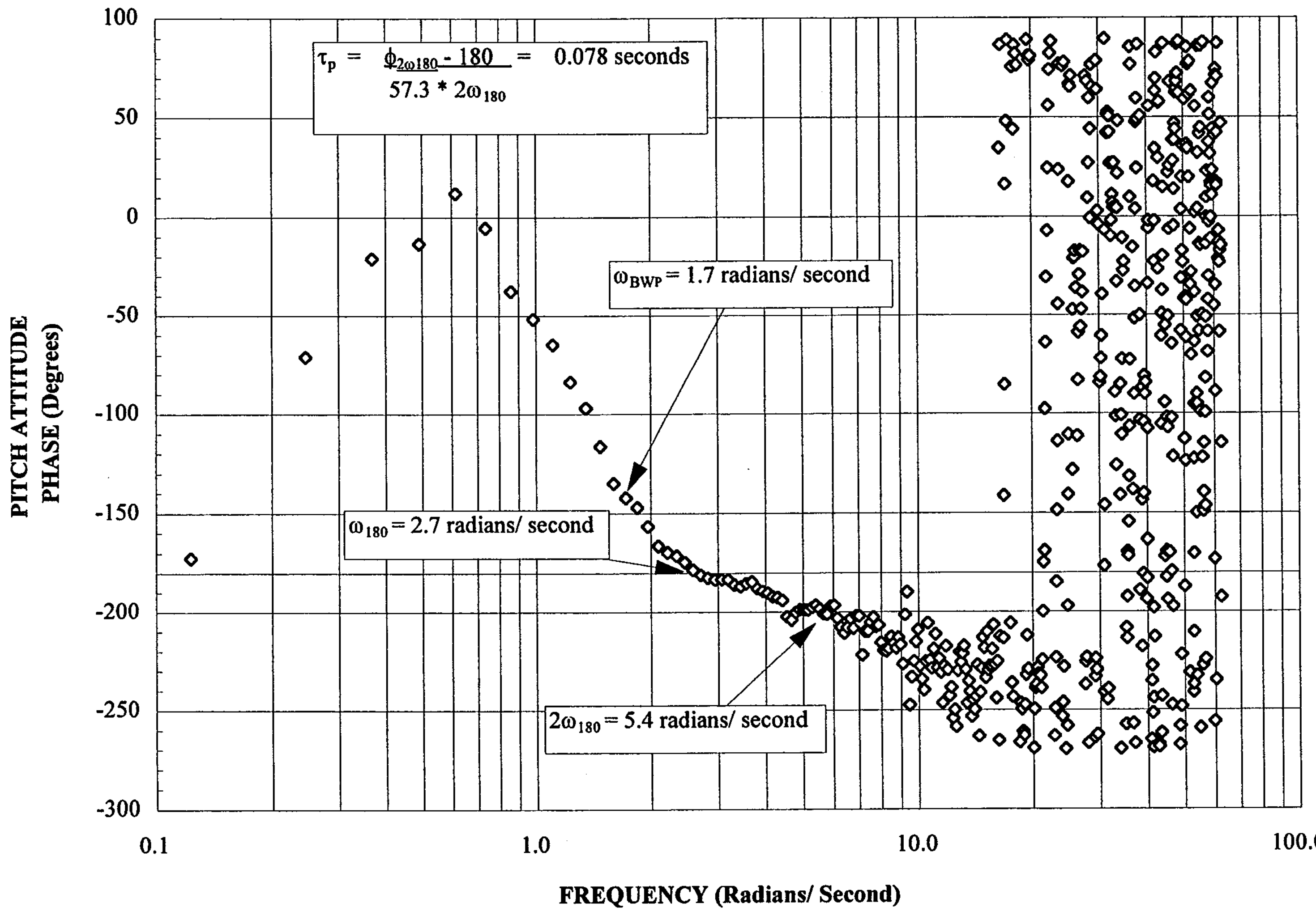

Figure J87 VSS Configuration J Phase Bode Plot

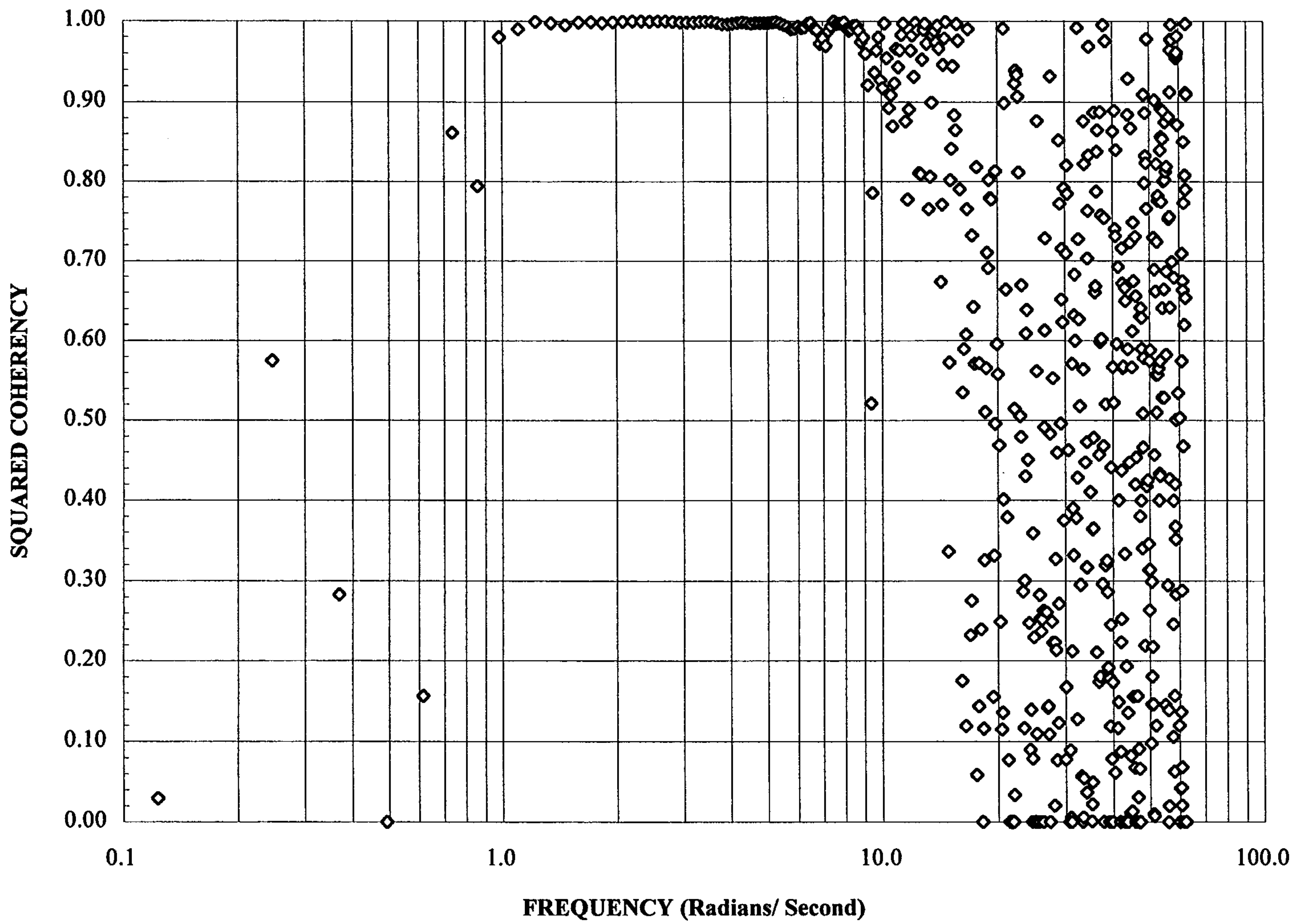

Figure J88 VSS Configuration J Bode Squared Coherency Plot

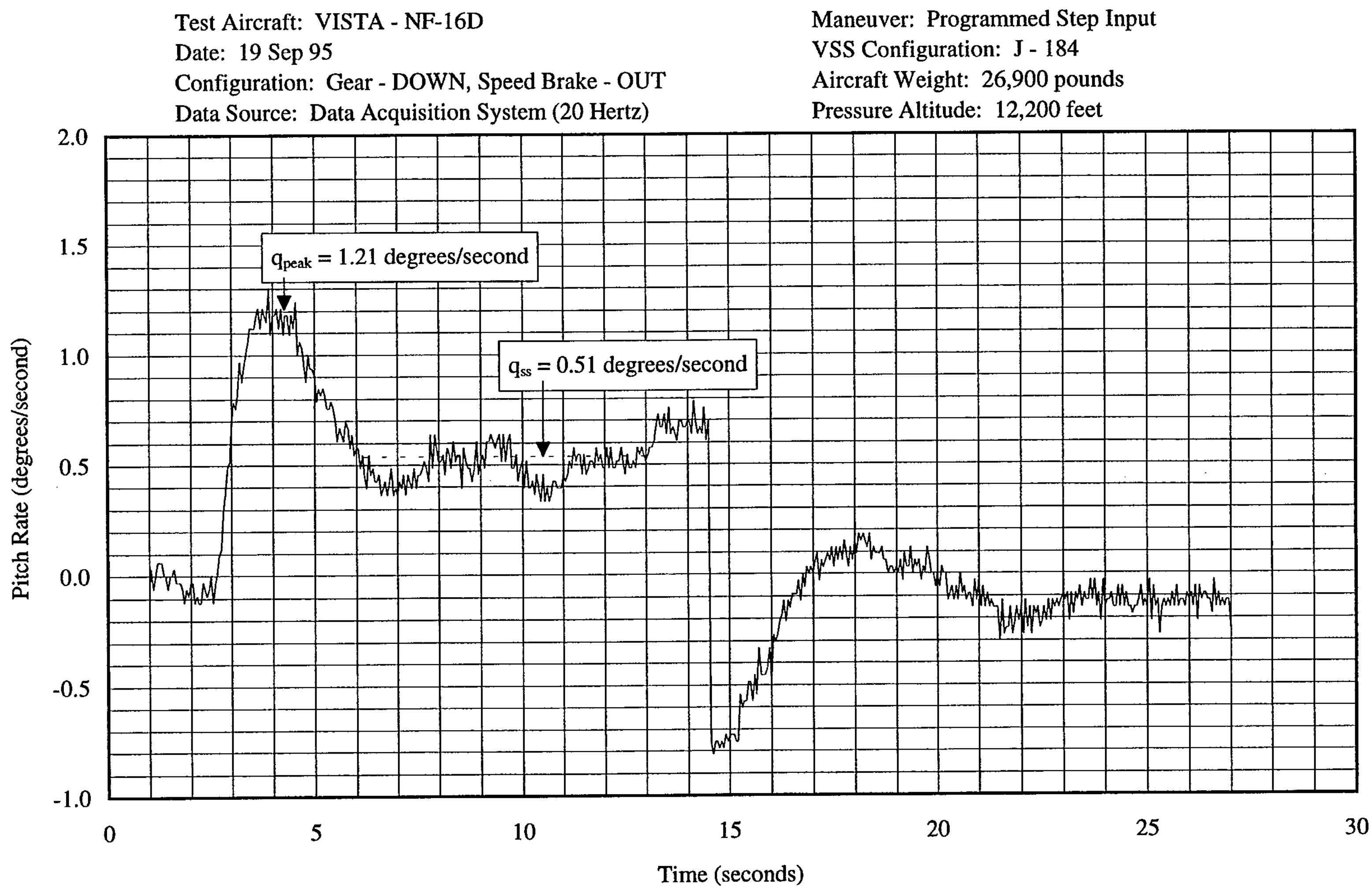

Figure J89 VSS Configuration J Pitch Rate Dropback

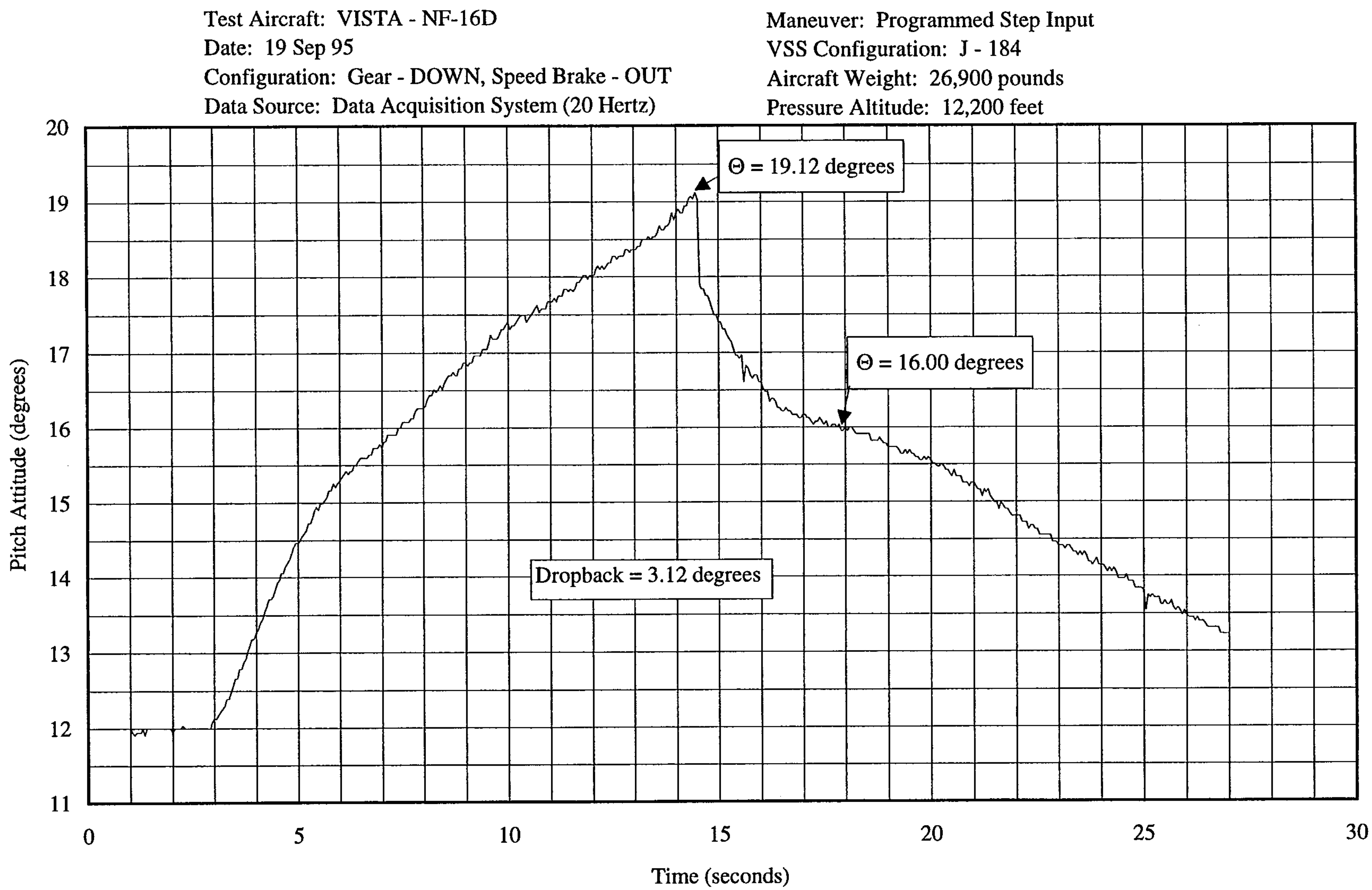

Figure J90 VSS Configuration J Pitch Angle Dropback

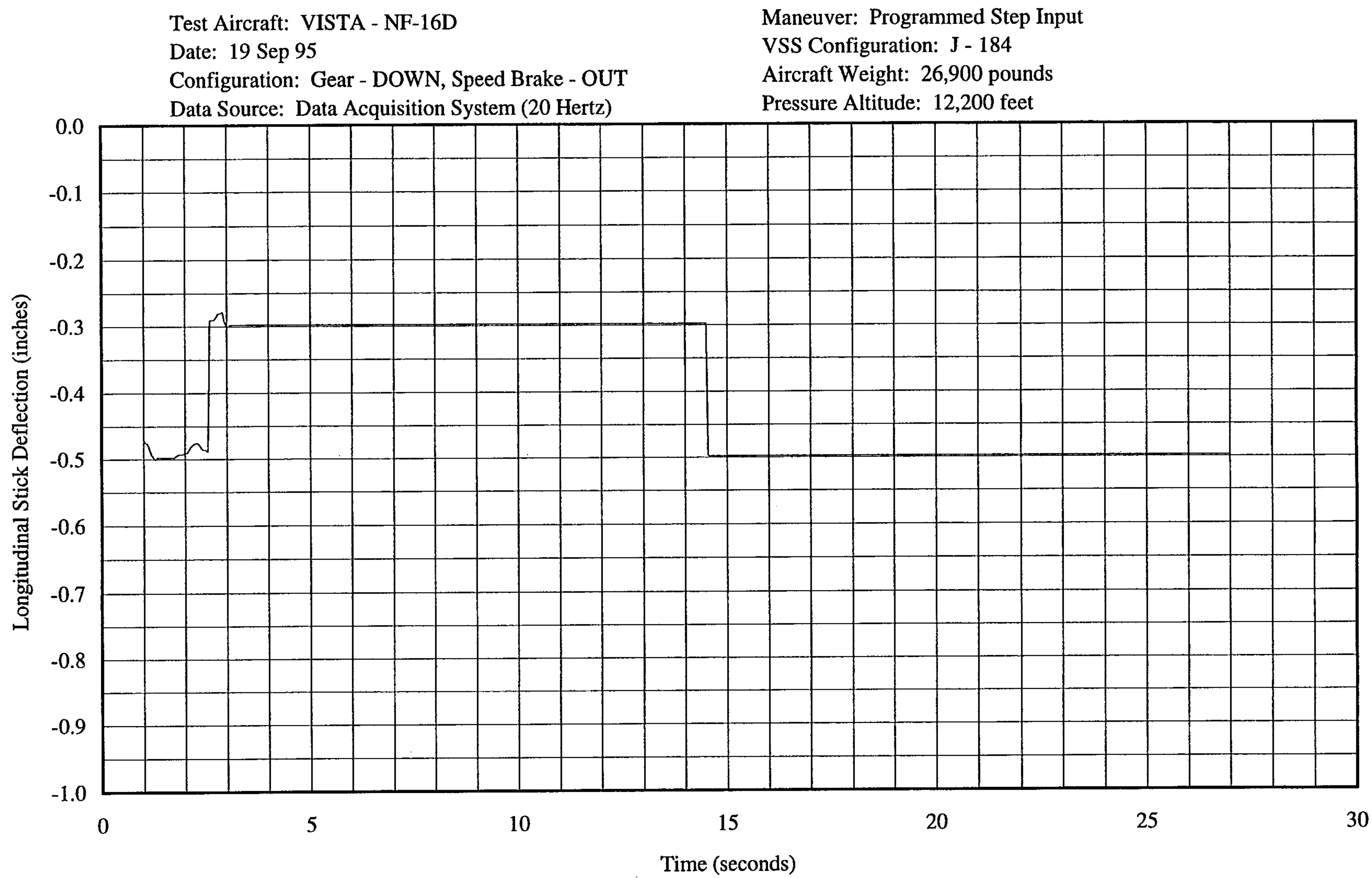

Figure J91 VSS Configuration J Pitch Input Dropback

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: J - 184
Pilot: 2
Test Point: 3.2
Aircraft Weight: 27,400 pounds

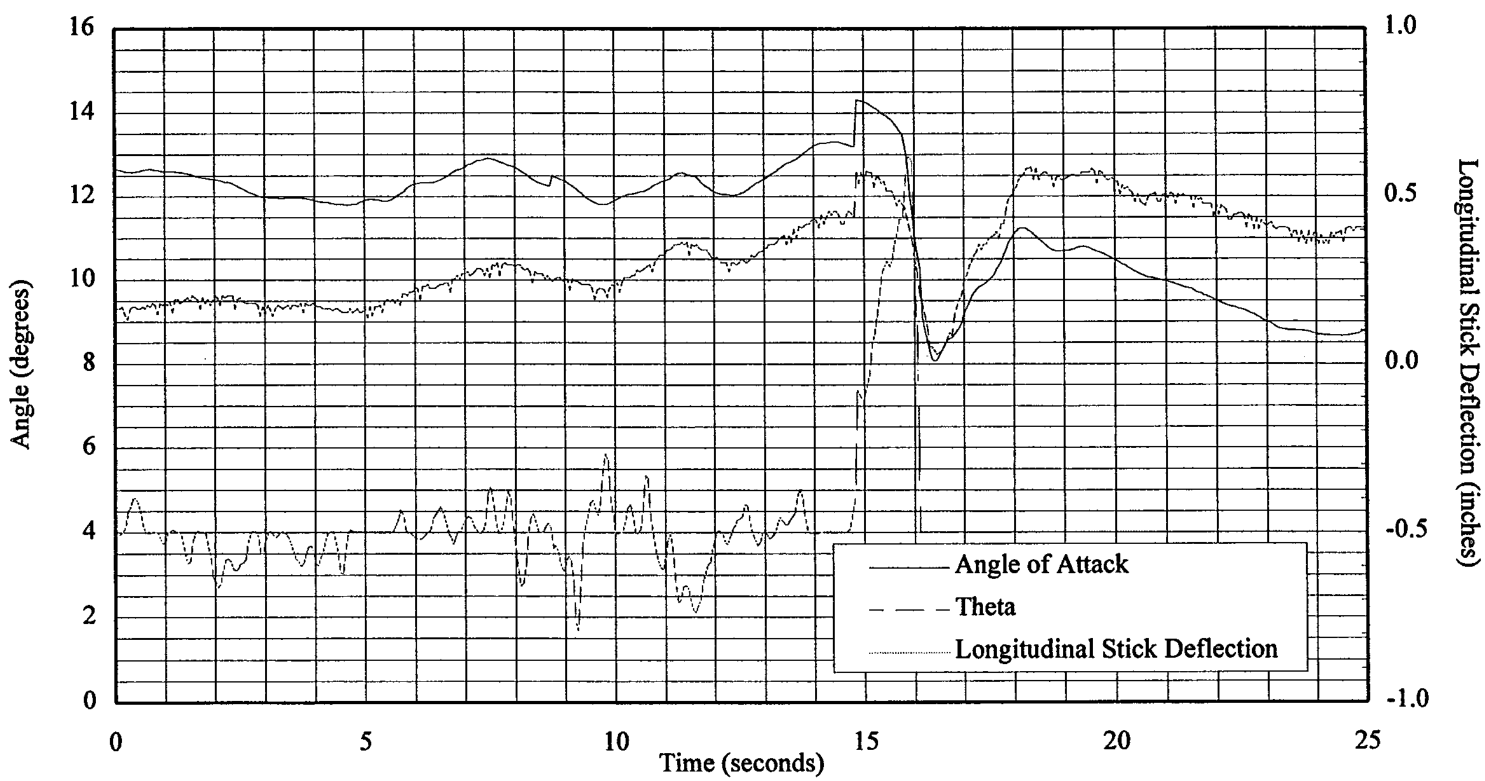

Figure J92 VSS Configuration J Time History of Theta and Longitudinal Stick Deflection

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: J - 184
Pilot: 2
Test Point: 3.2
Aircraft Weight: 27,400 pounds

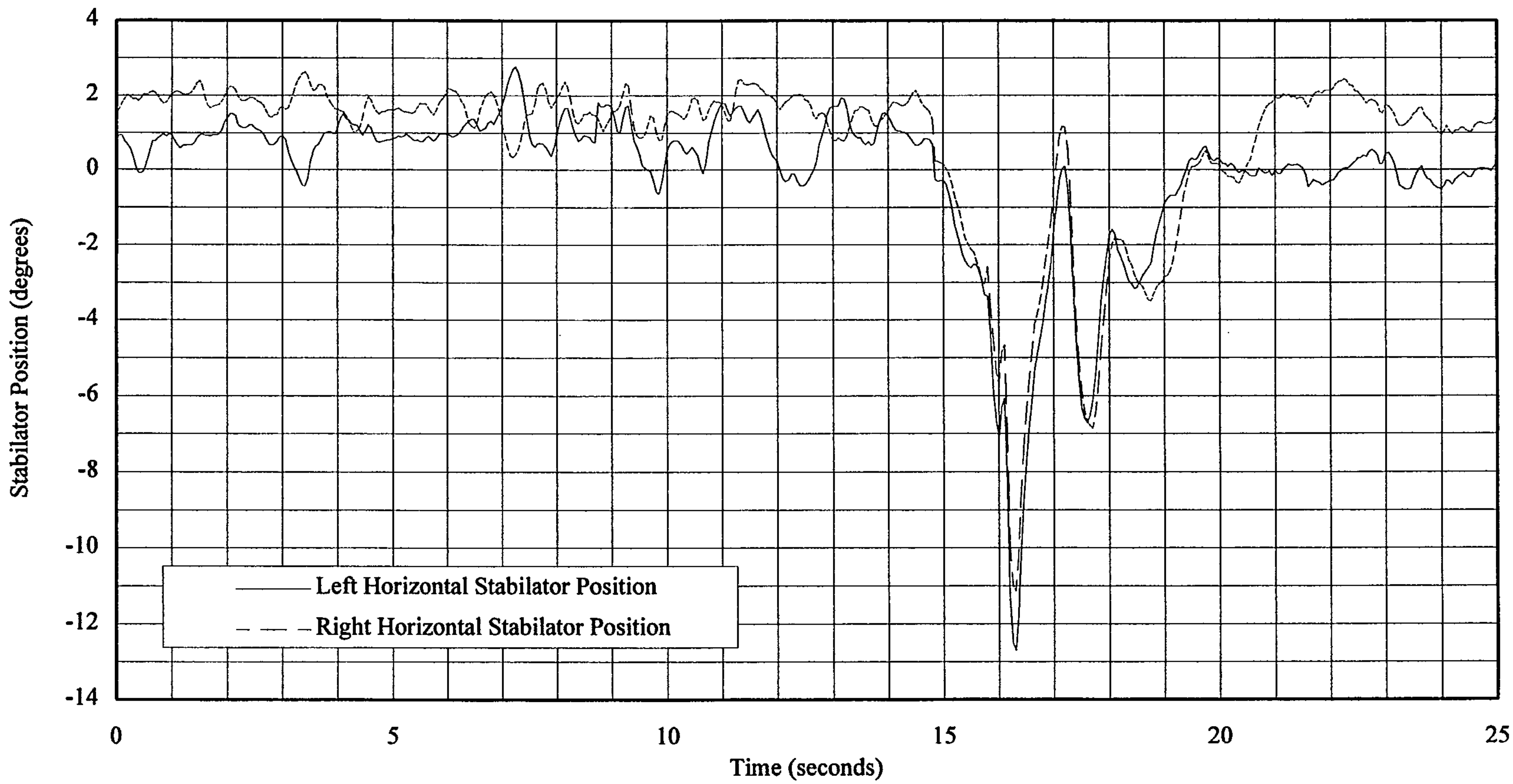

Figure J93 VSS Configuration J Time History of Stabilator Movement

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: J - 184
Pilot: 2
Test Point: 3.2
Aircraft Weight: 27,400 pounds

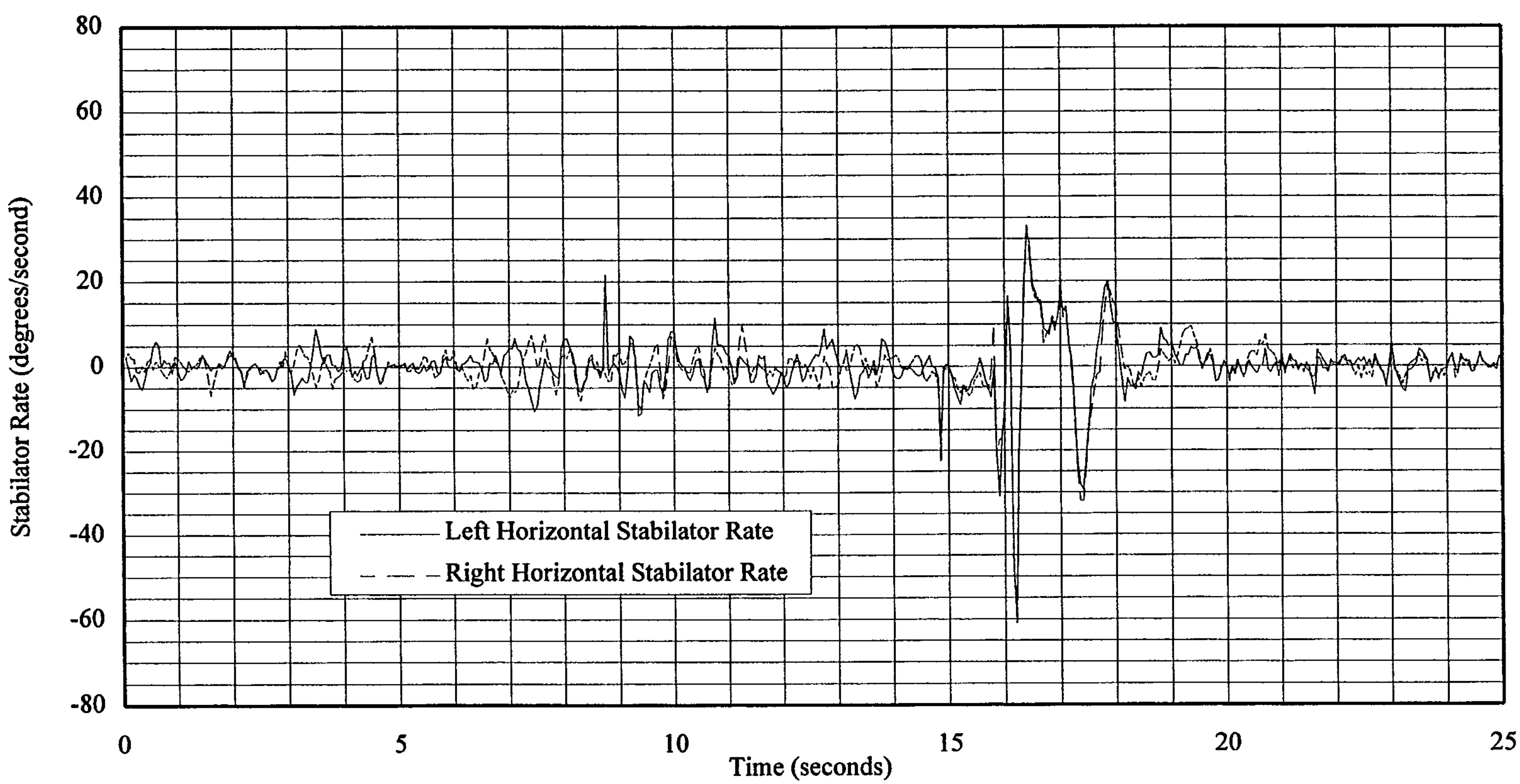

Figure J94 VSS Configuration J Time History of Stabilator Rate

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: J - 184
Pilot: 2
Test Point: 3.2
Aircraft Weight: 27,400 pounds

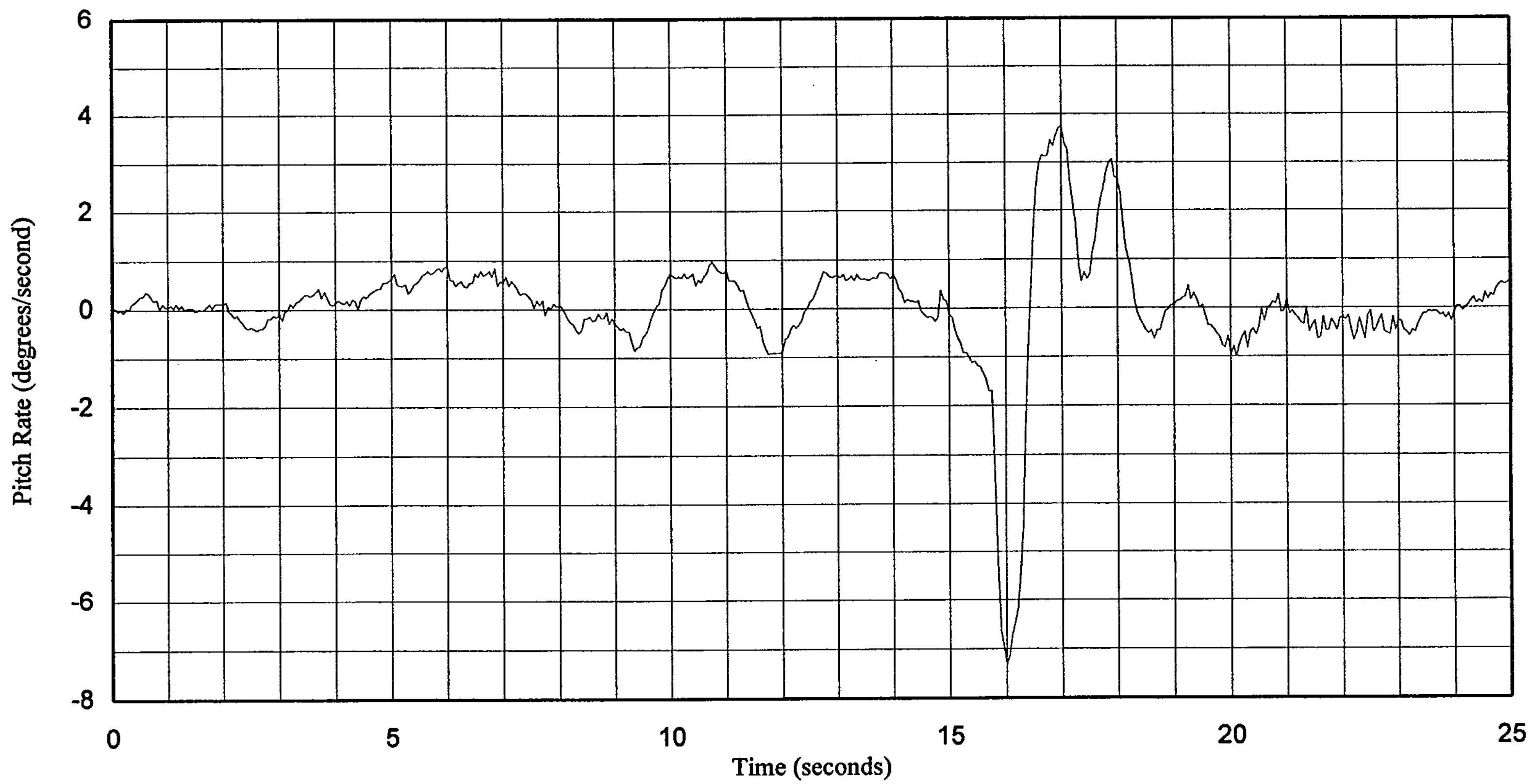

Figure J95 VSS Configuration J Time History of Pitch Rate

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: J - 184
Pilot: 2
Test Point: 3.2
Aircraft Weight: 27,400 pounds

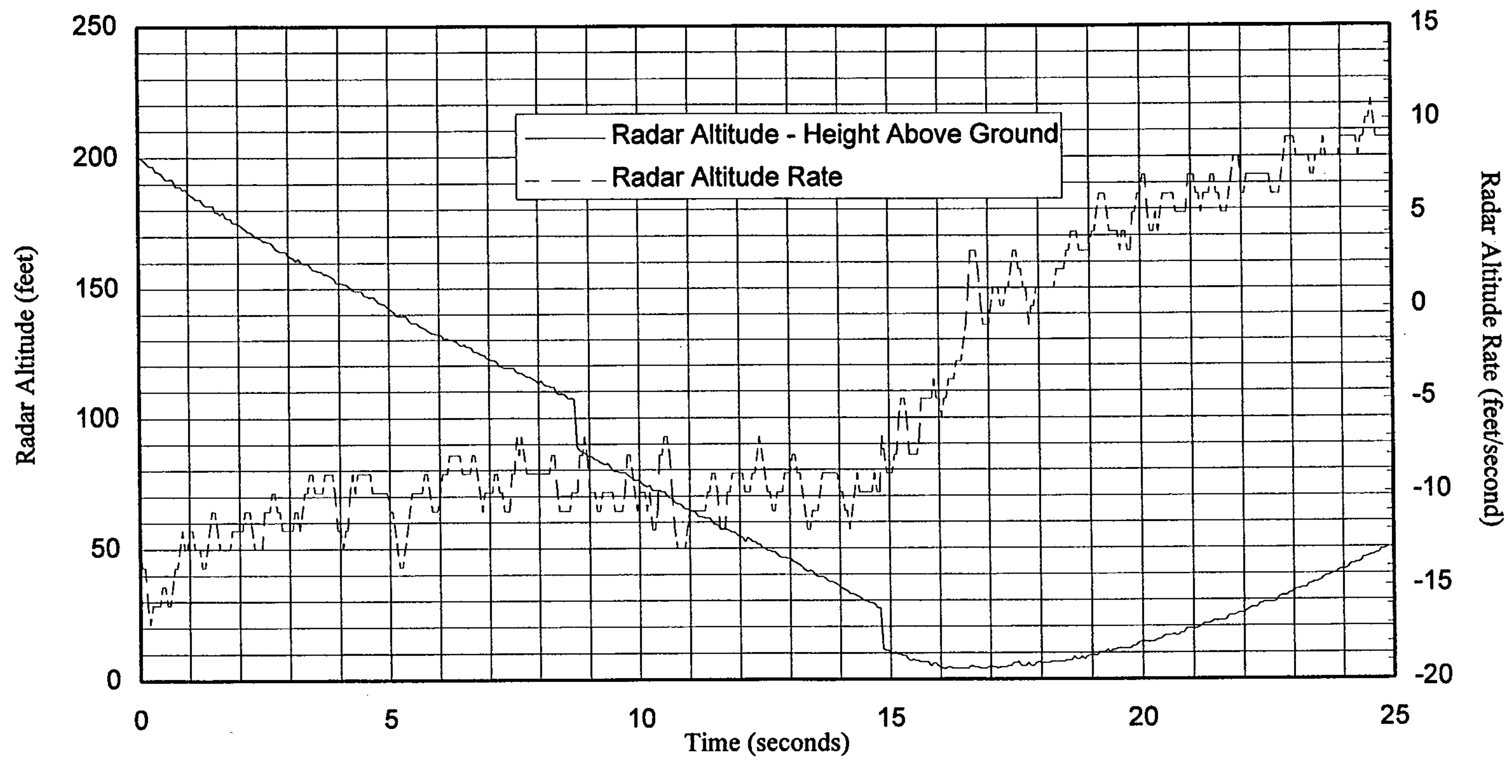

Figure J96 VSS Configuration J Time History of Altitude and Descent Rate

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: J - 184
Pilot: 2
Test Point: 3.2
Aircraft Weight: 27,400 pounds

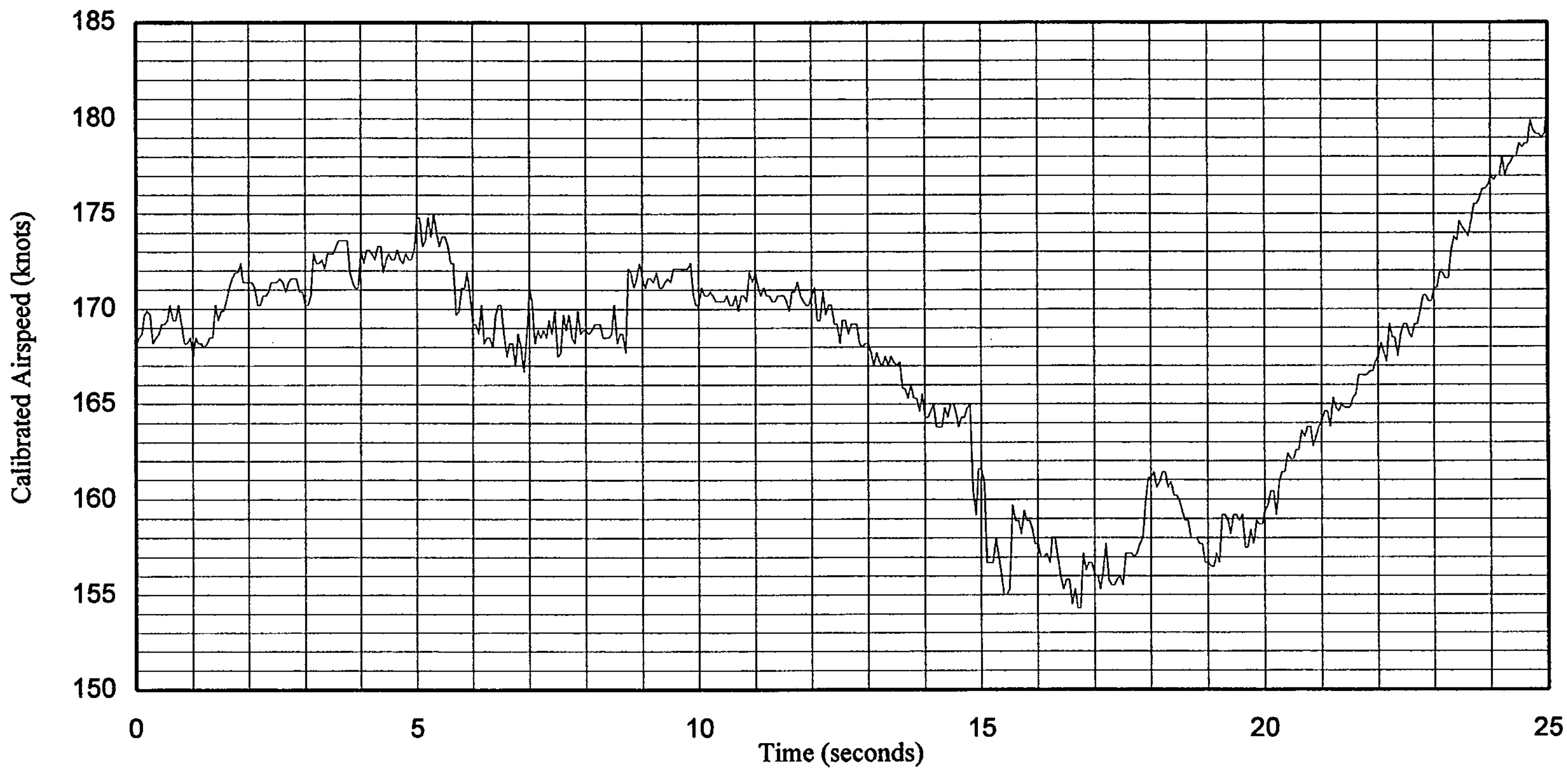

Figure J97 VSS Configuration J Time History of Calibrated Airspeed

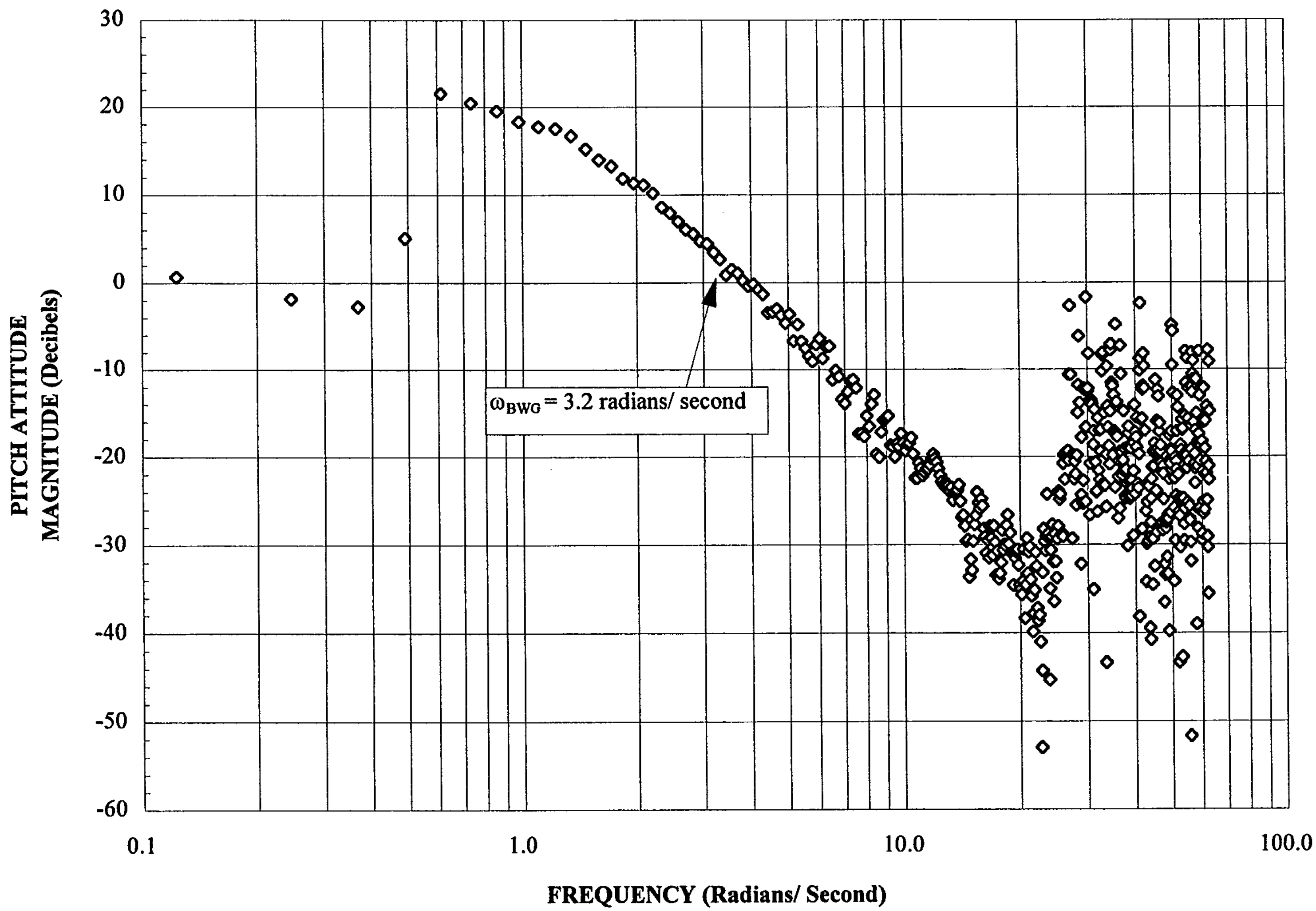

Figure J98 VSS Configuration K Magnitude Bode Plot

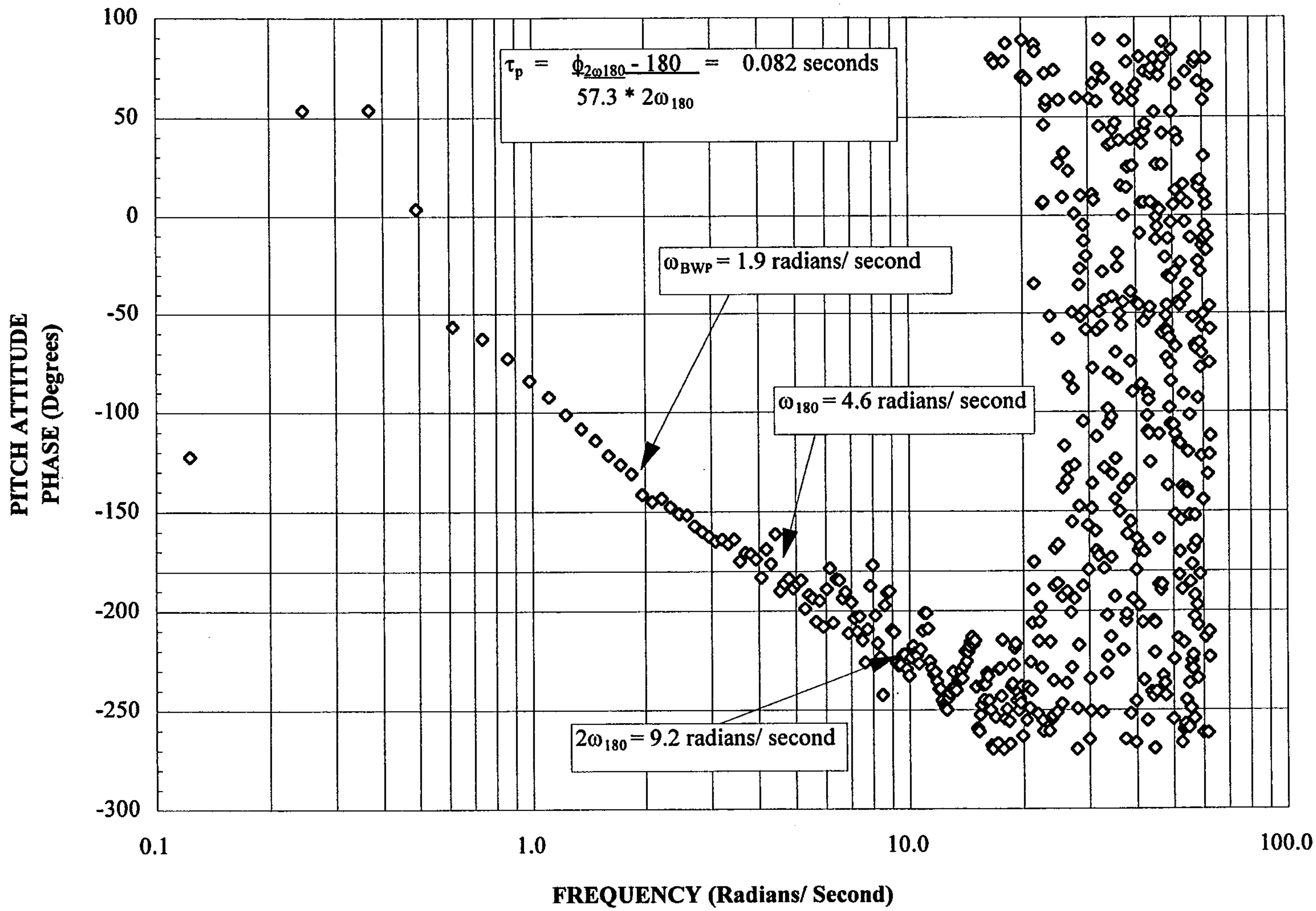

Figure J99 VSS Configuration K Phase Bode Plot

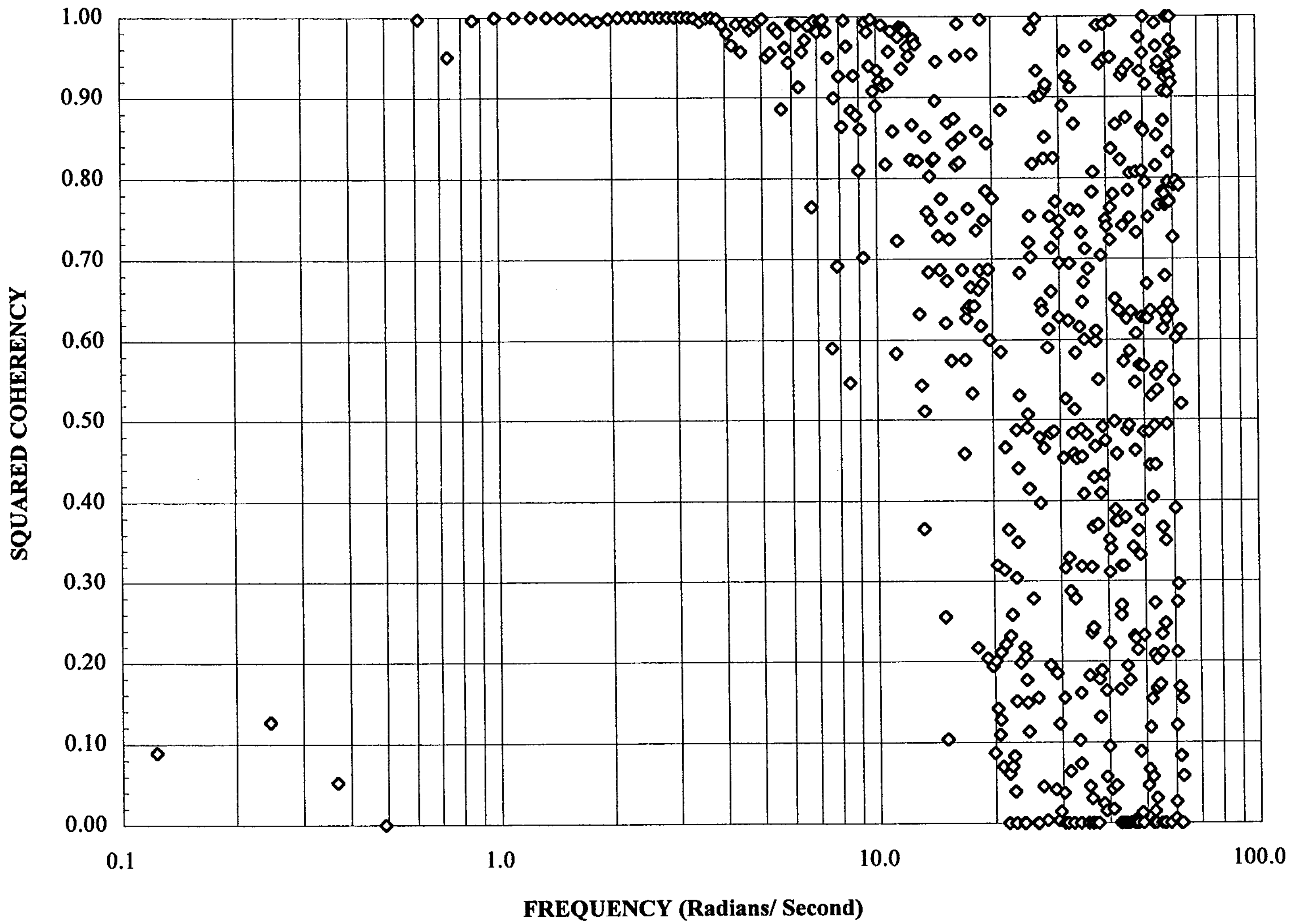

Figure J100 VSS Configuration K Bode Squared Coherency Plot

Test Aircraft: VISTA - NF-16D
Date: 19 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)

Maneuver: Programmed Step Input
VSS Configuration: K - 171
Aircraft Weight: 26,700 pounds
Pressure Altitude: 11,900 feet

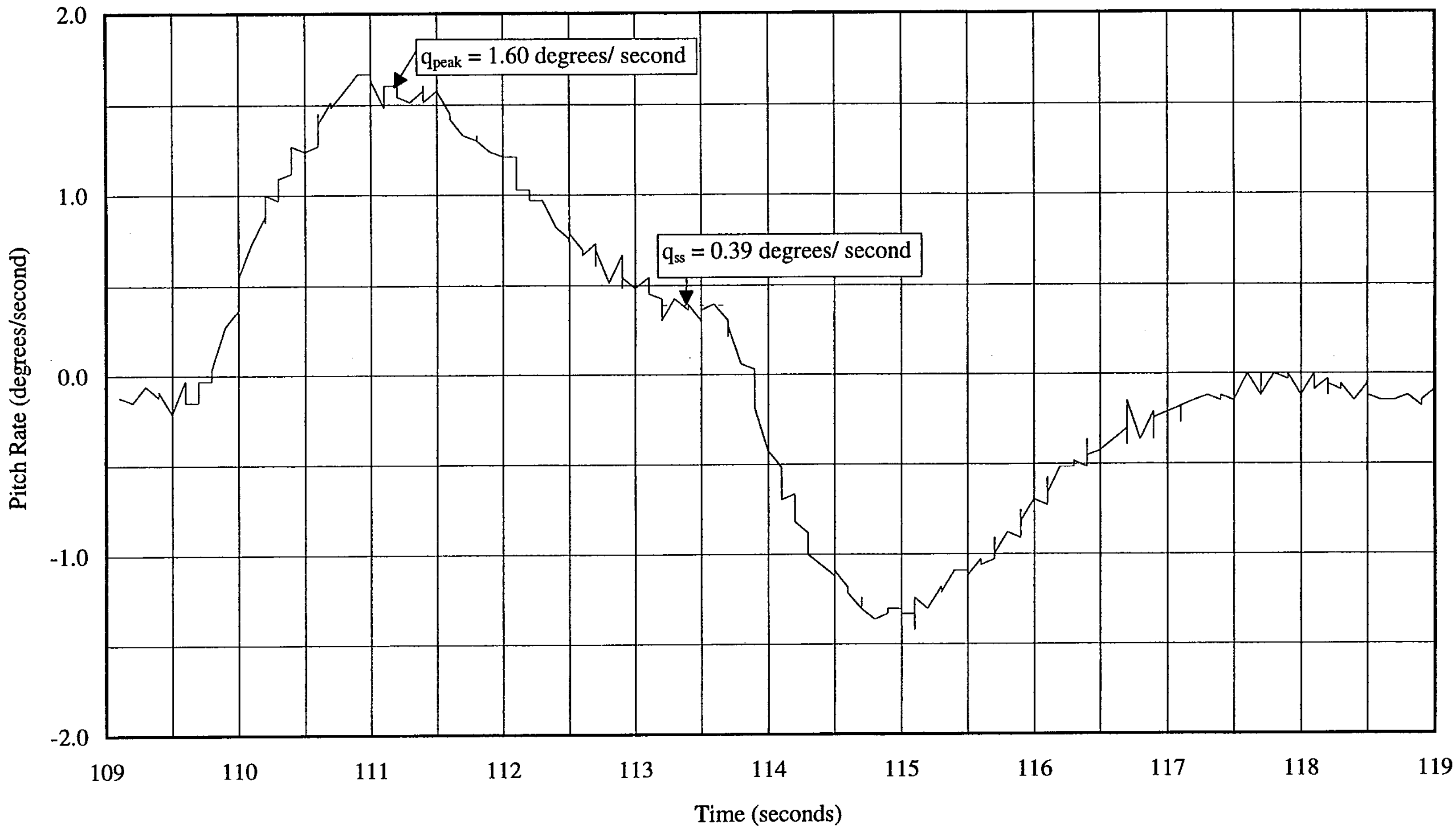

Figure J101 VSS Configuration K Pitch Rate Dropback

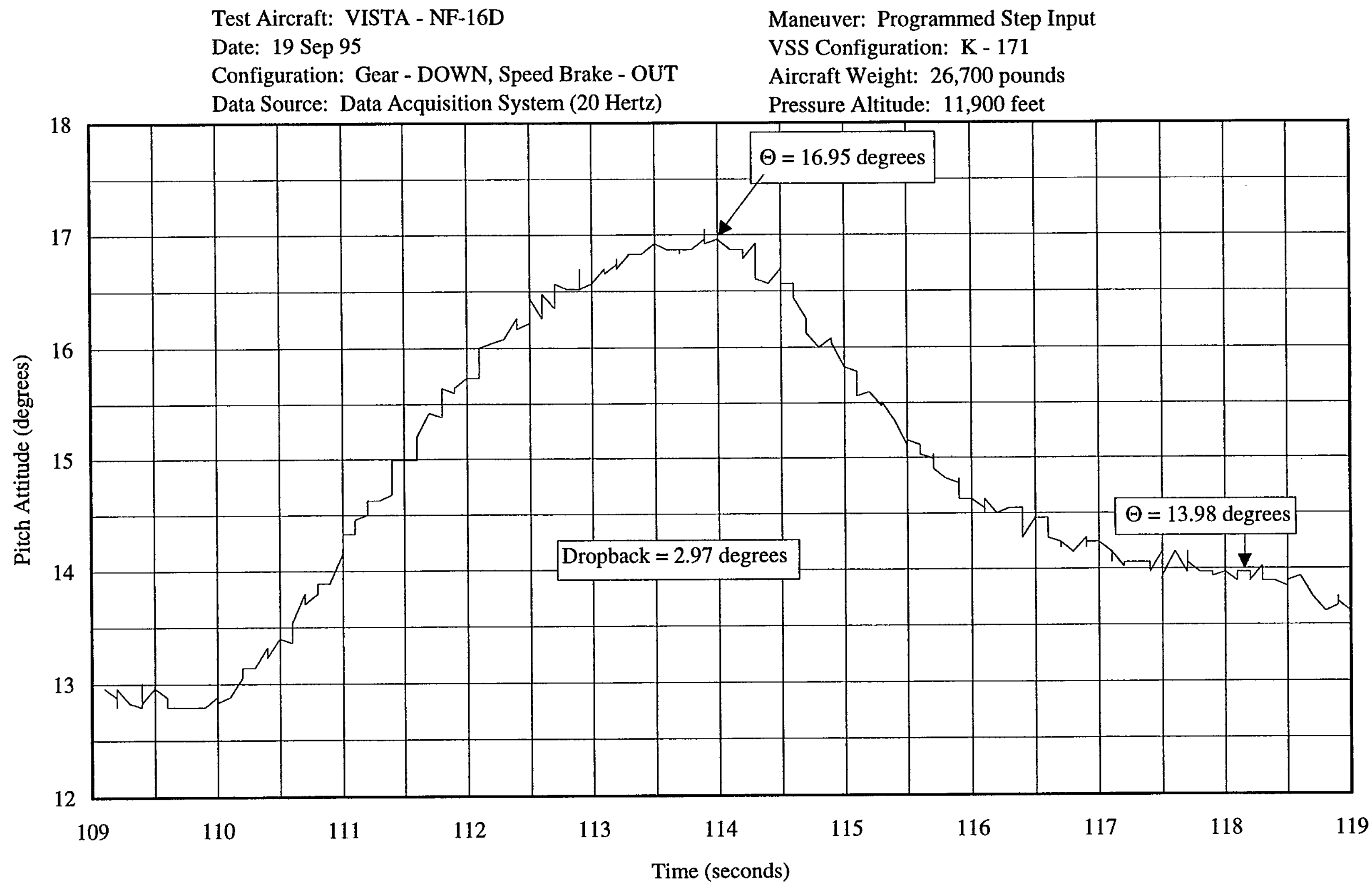

Figure J102 VSS Configuration K Pitch Angle Dropback

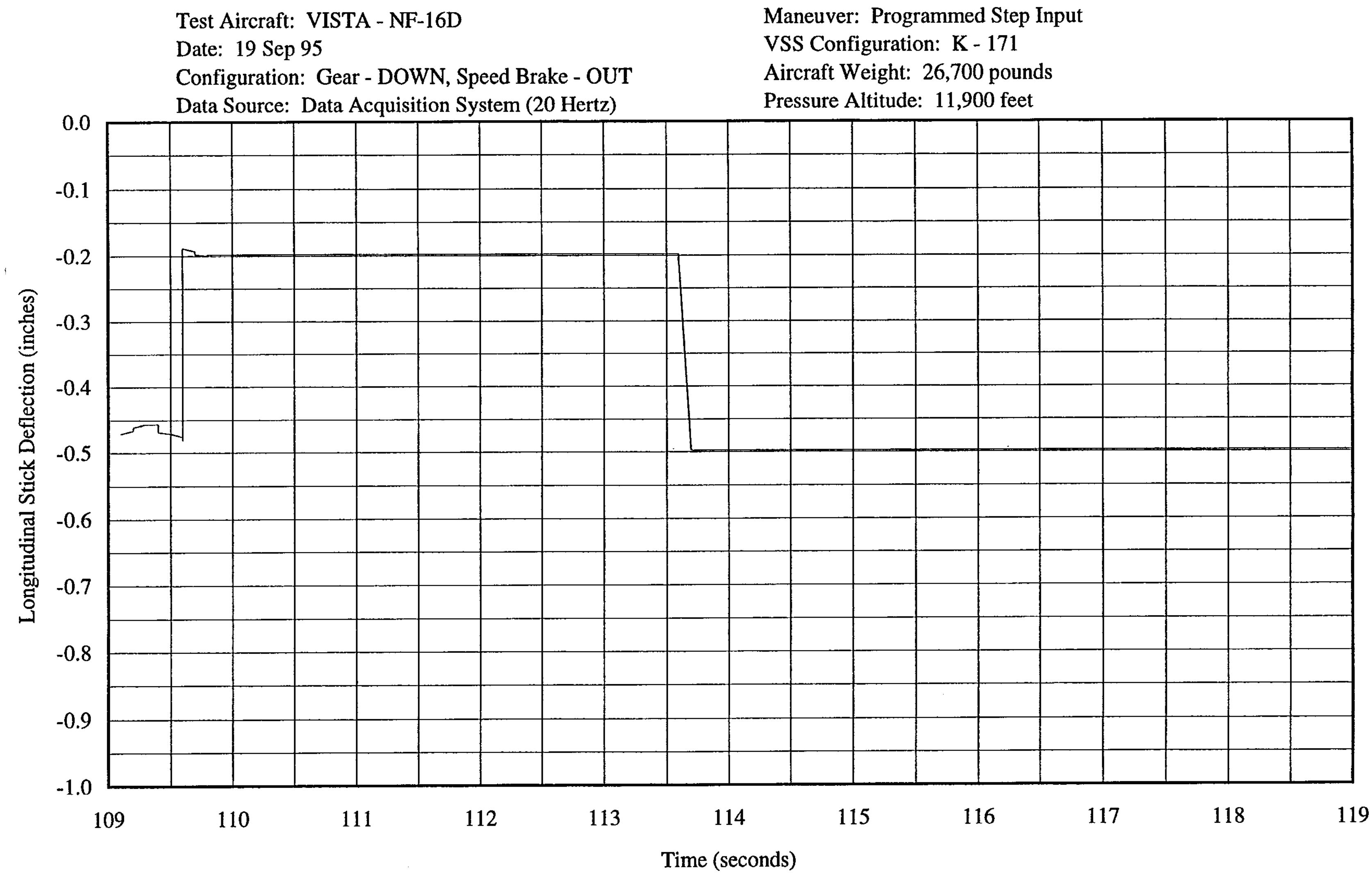

Figure J103 VSS Configuration K Pitch Input Dropback

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 97°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: K - 171
Pilot: 4
Test Point: 9.5
Aircraft Weight: 24,300 pounds

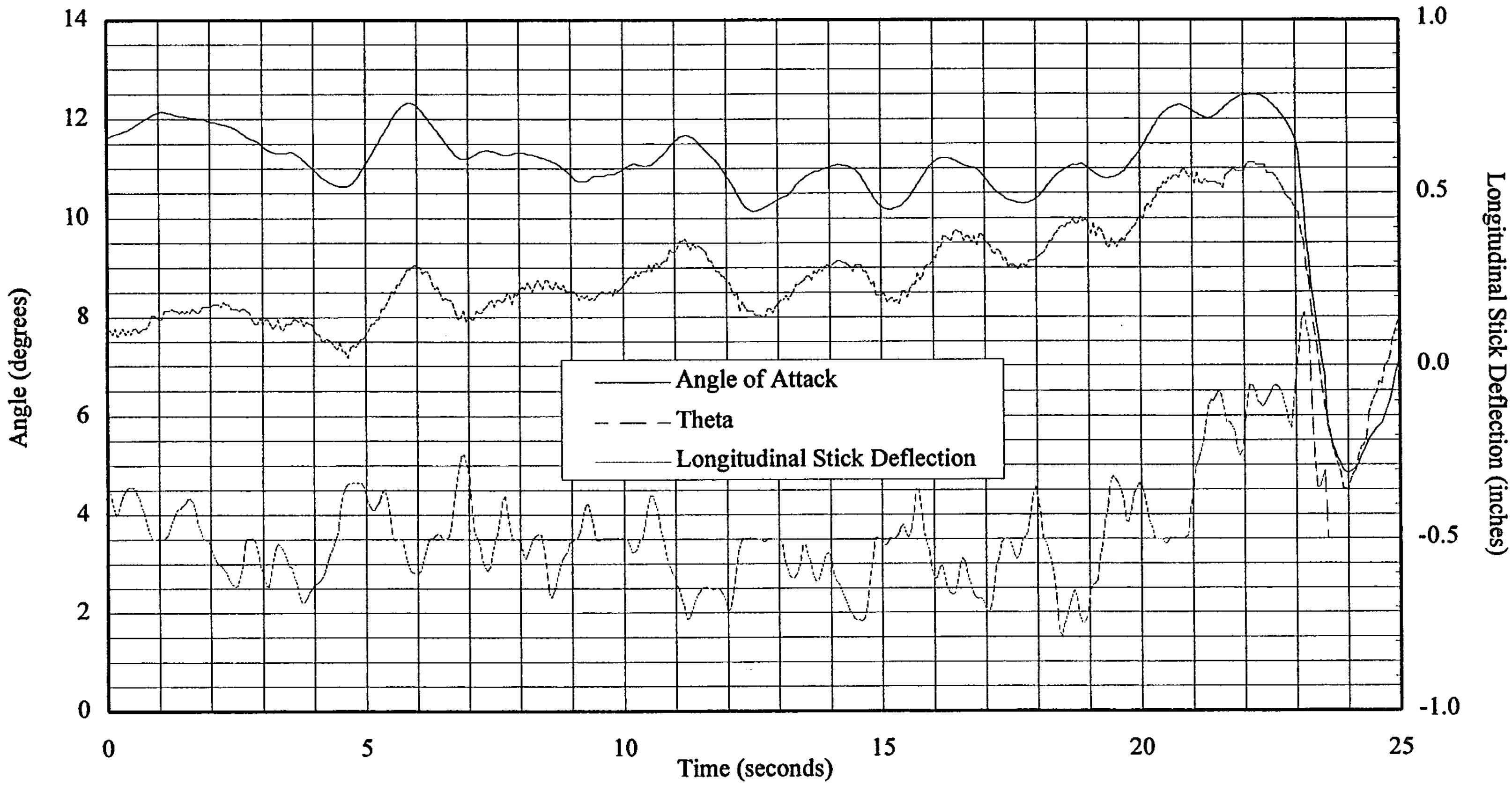

Figure J104 VSS Configuration K Time History of Theta and Longitudinal Stick Deflection

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 97°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: K - 171
Pilot: 4
Test Point: 9.5
Aircraft Weight: 24,300 pounds

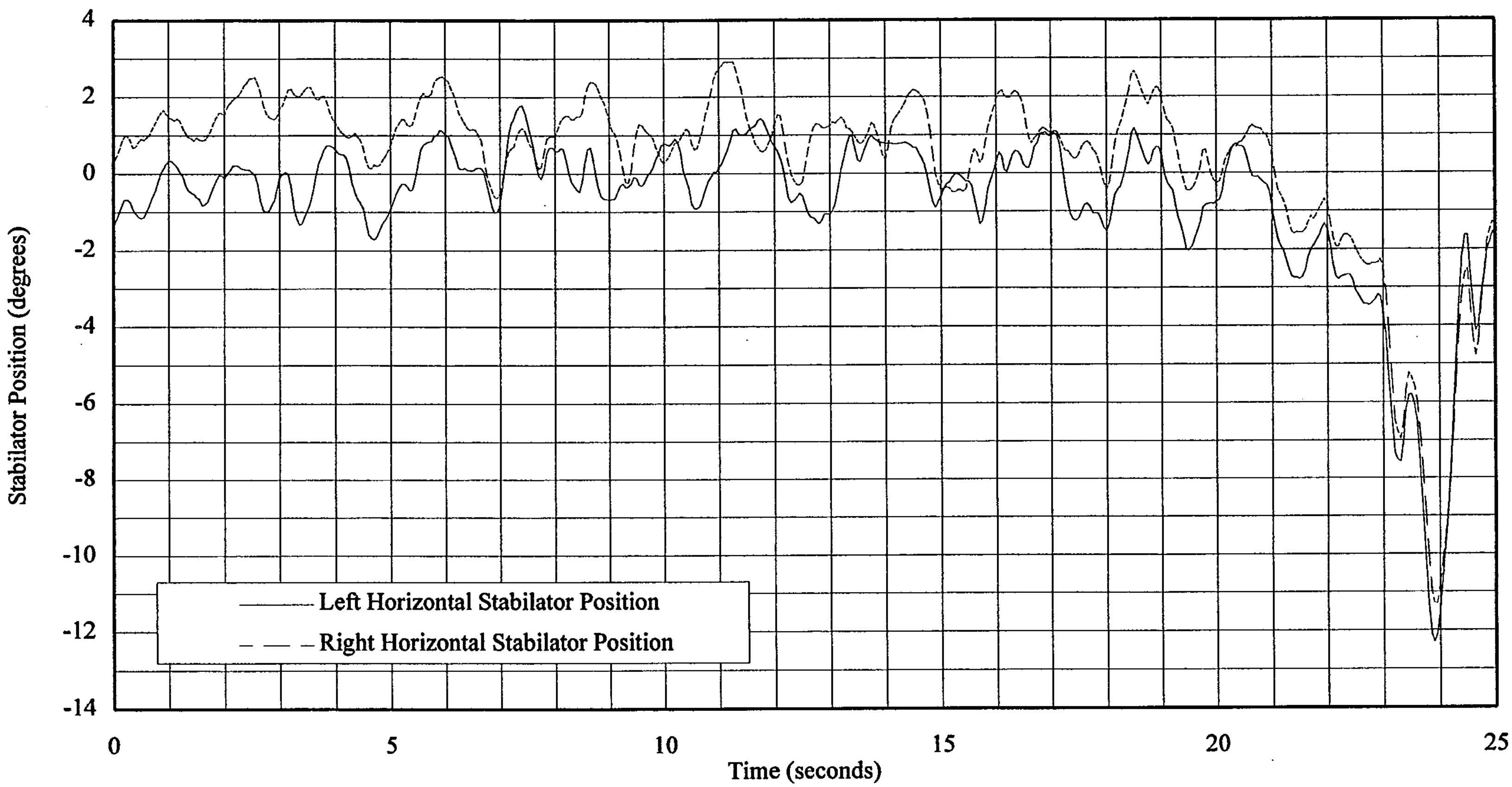

Figure J105 VSS Configuration K Time History of Stabilator Movement

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 97°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: K - 171
Pilot: 4
Test Point: 9.5
Aircraft Weight: 24,300 pounds

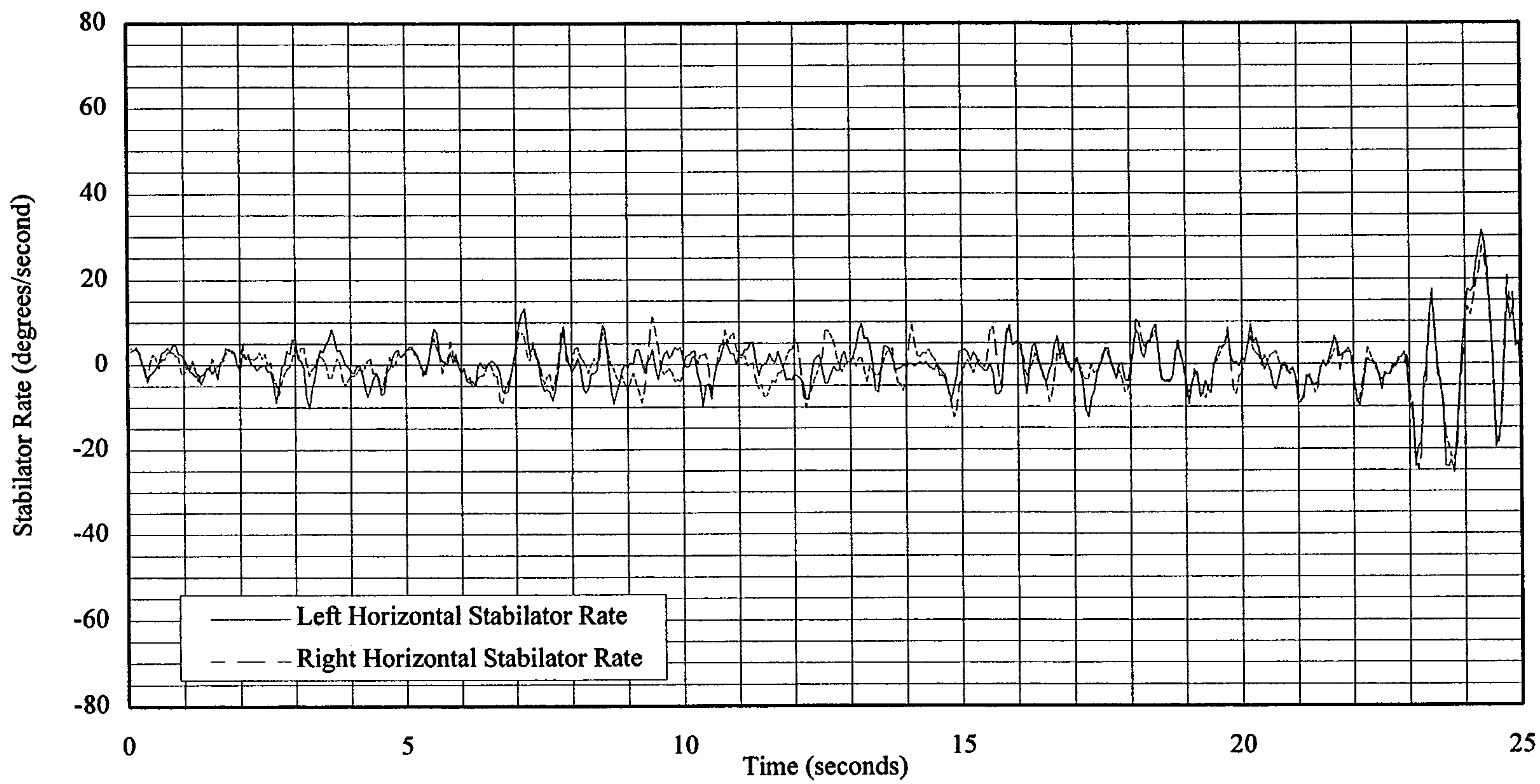

Figure J106 VSS Configuration K Time History of Stabilator Rate

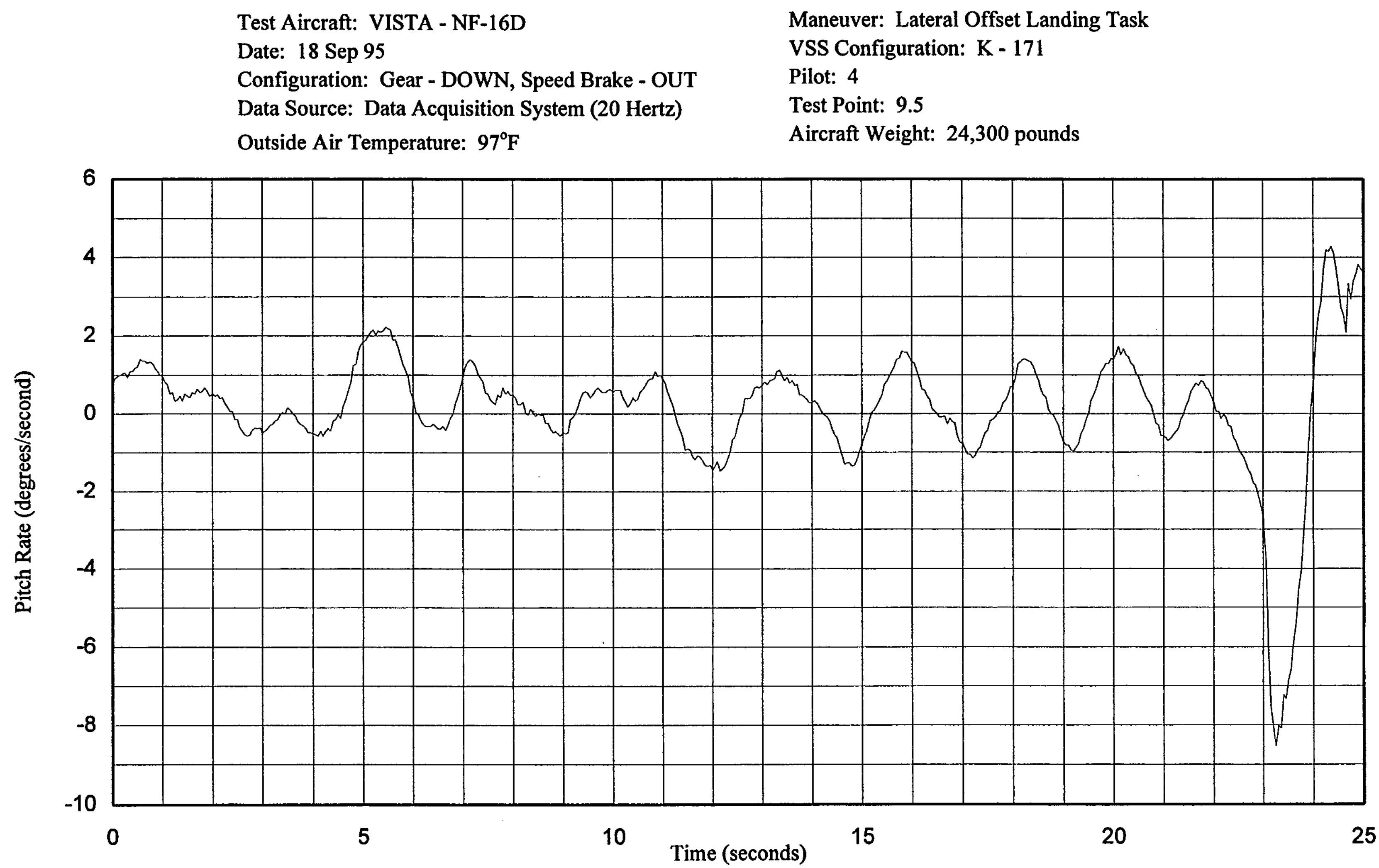

Figure J107 VSS Configuration K Time History of Pitch Rate

Test Aircraft: VISTA - NF-16D
Date: 18 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 97°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: K - 171
Pilot: 4
Test Point: 9.5
Aircraft Weight: 24,300 pounds

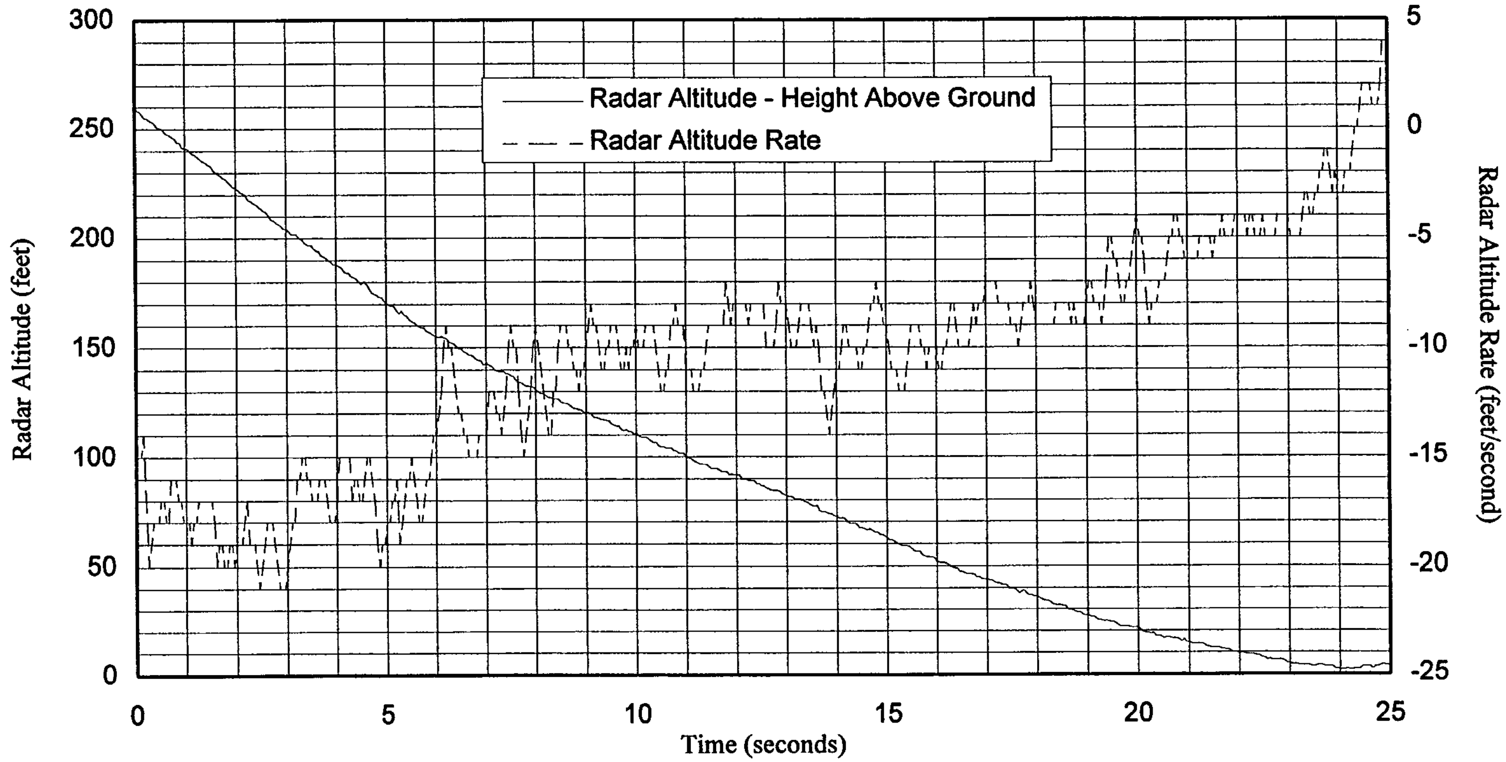

Figure J108 VSS Configuration K Time History of Altitude and Descent Rate

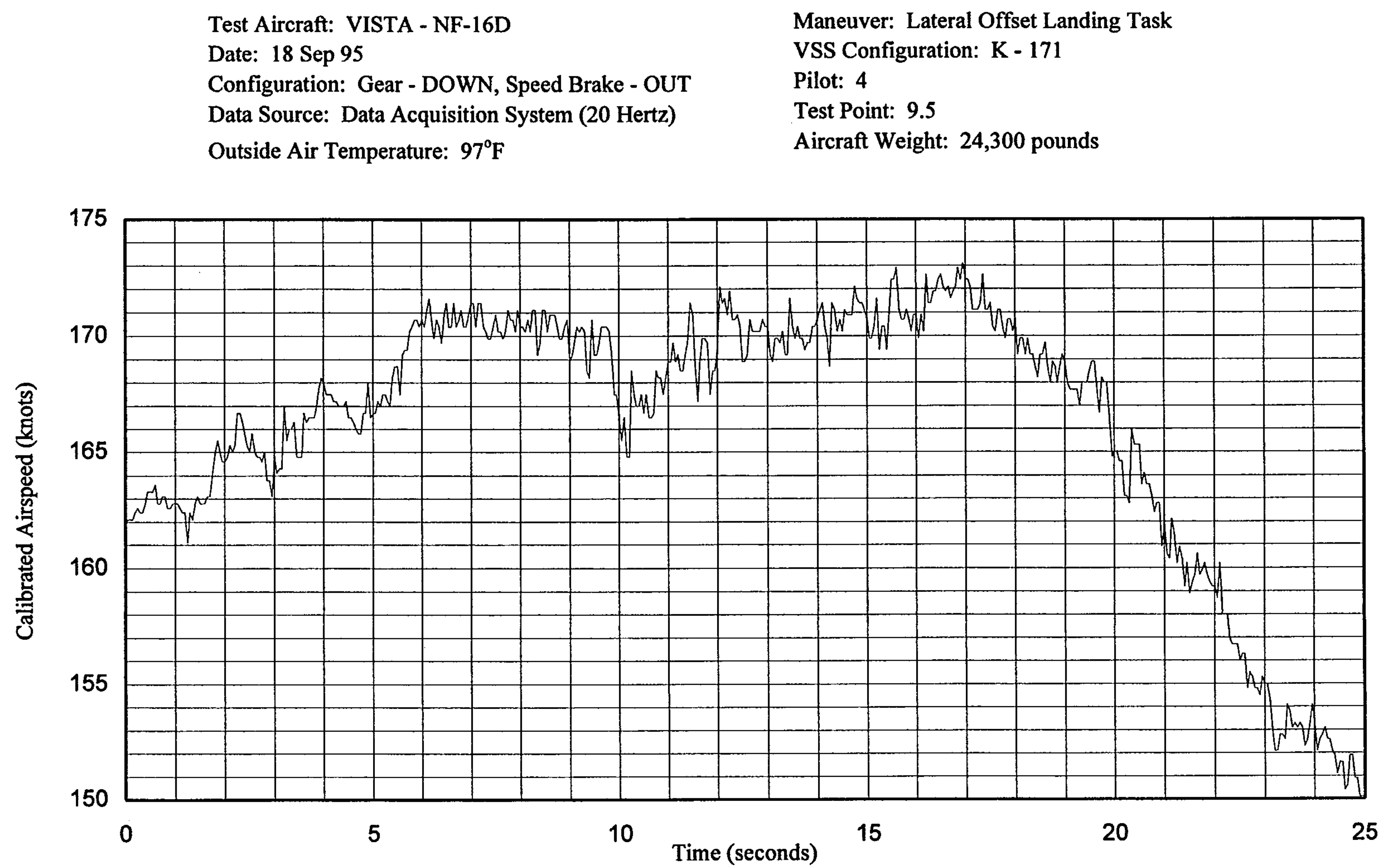

Figure J109 VSS Configuration K Time History of Calibrated Airspeed

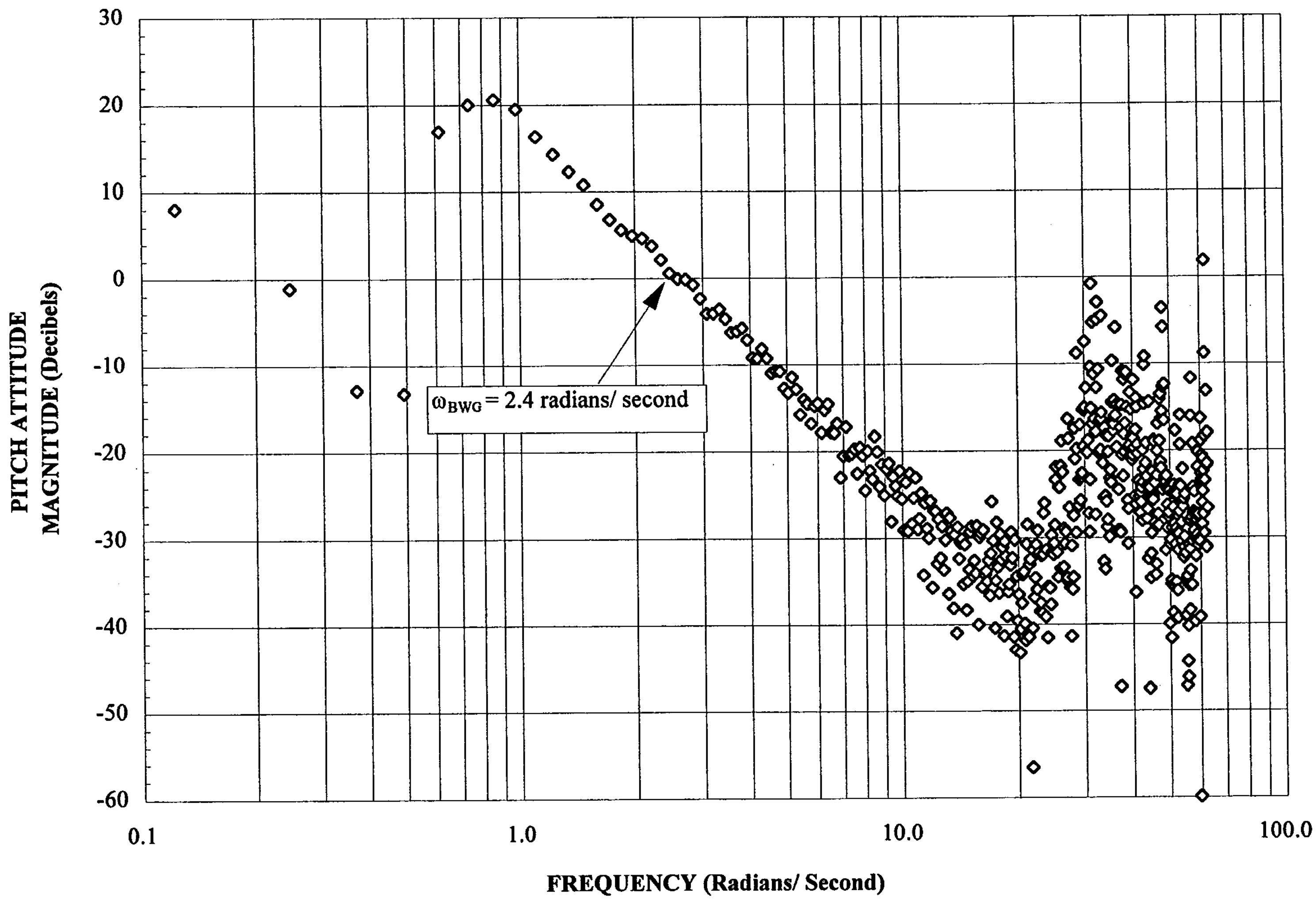

Figure J110 VSS Configuration P Magnitude Bode Plot

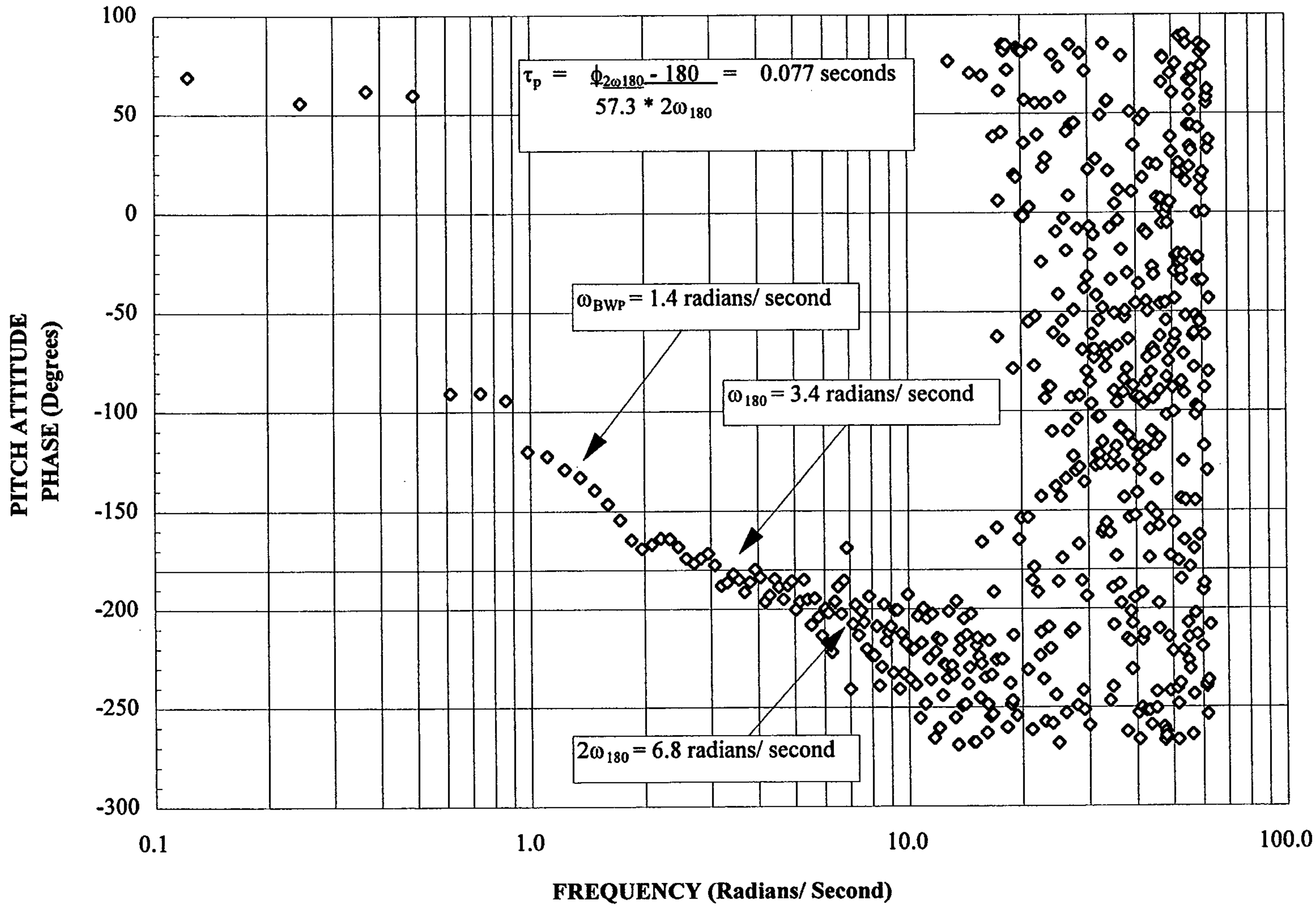

Figure J111 VSS Configuration P Phase Bode Plot

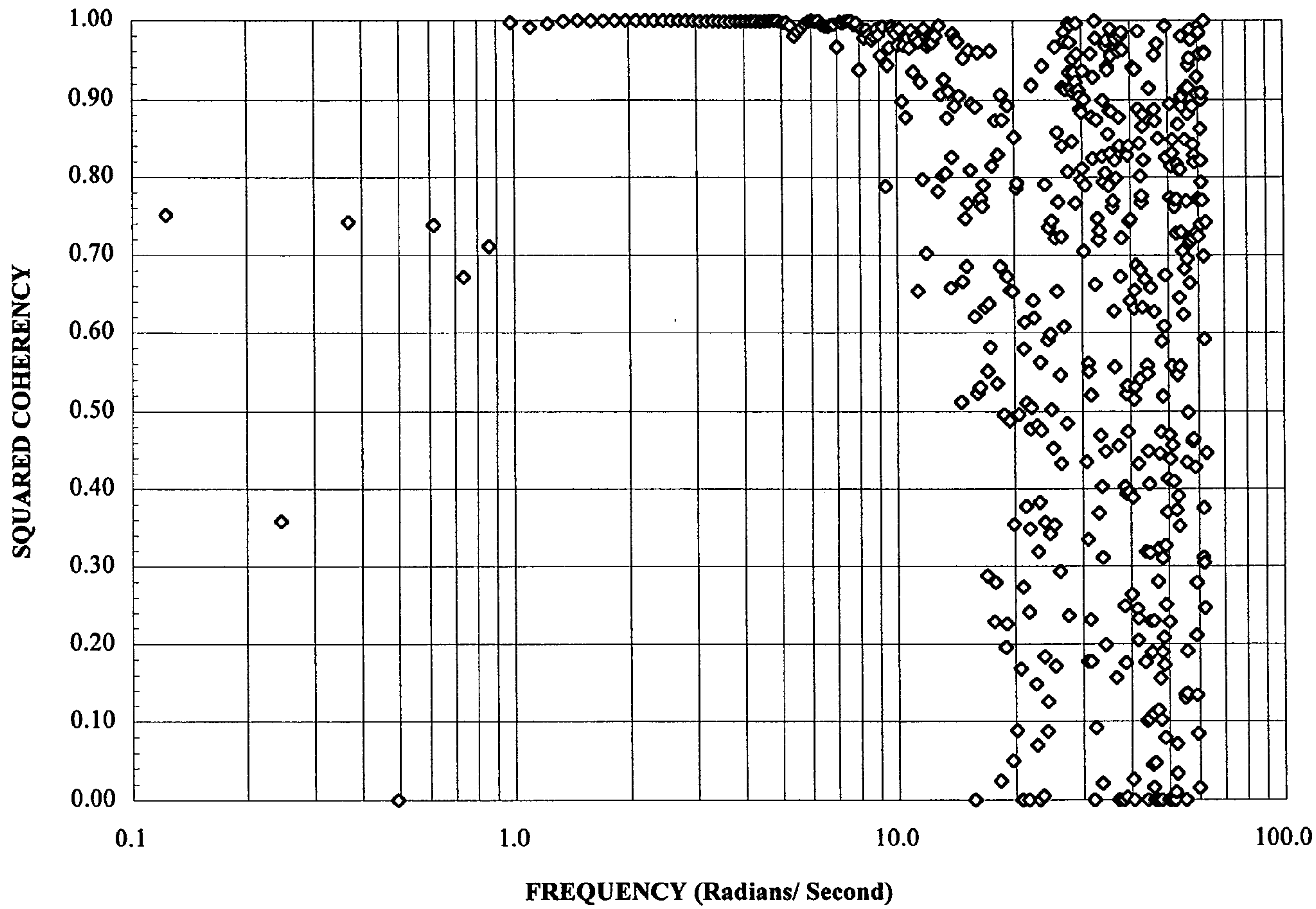

Figure J112 VSS Configuration P Bode Squared Coherency Plot

Test Aircraft: VISTA - NF-16D
Date: 22 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)

Maneuver: Programmed Step Input
VSS Configuration: P
Aircraft Weight: 28,000 pounds
Pressure Altitude: 11,000 feet

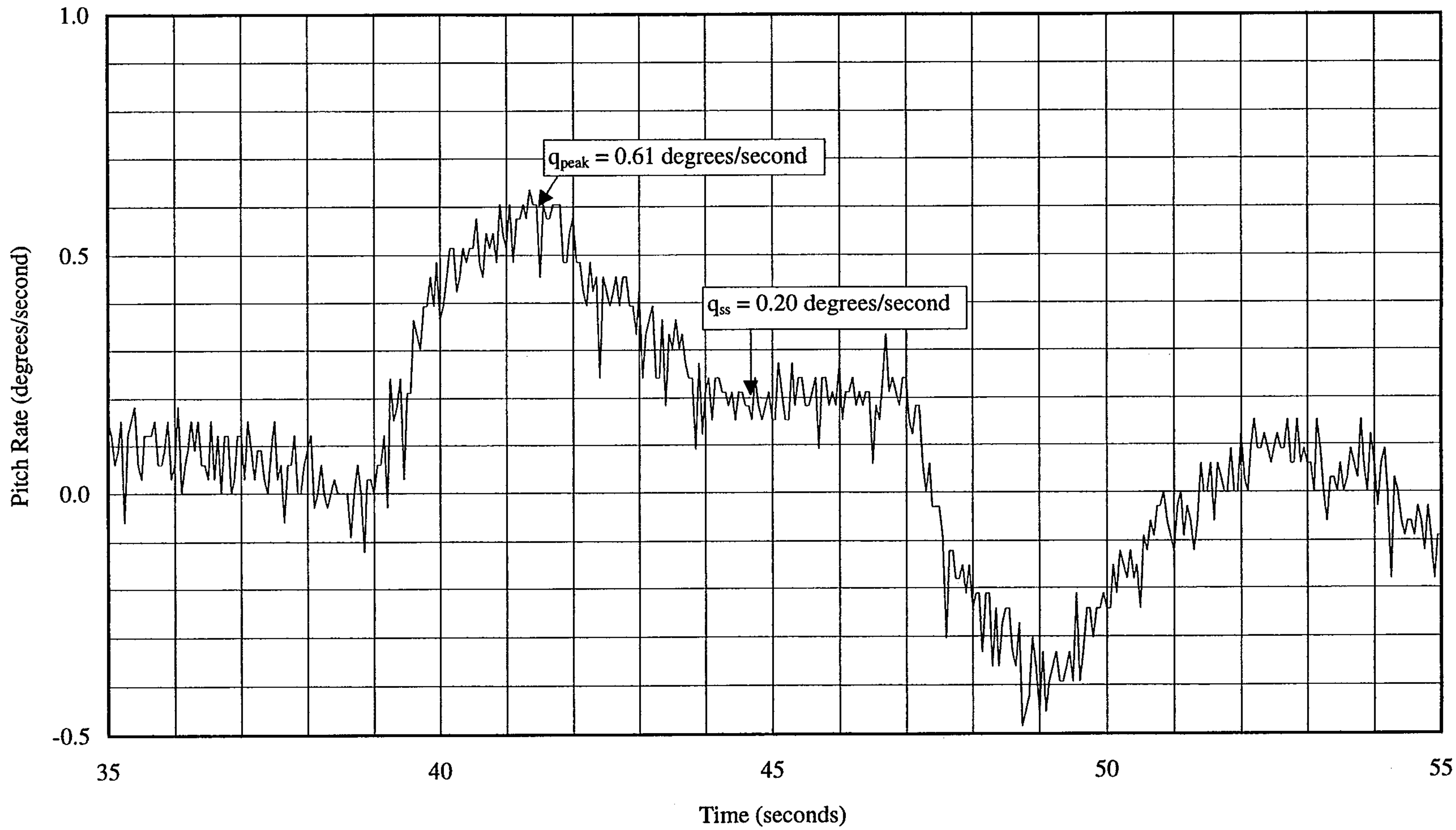

Figure J113 VSS Configuration P Pitch Rate Dropback

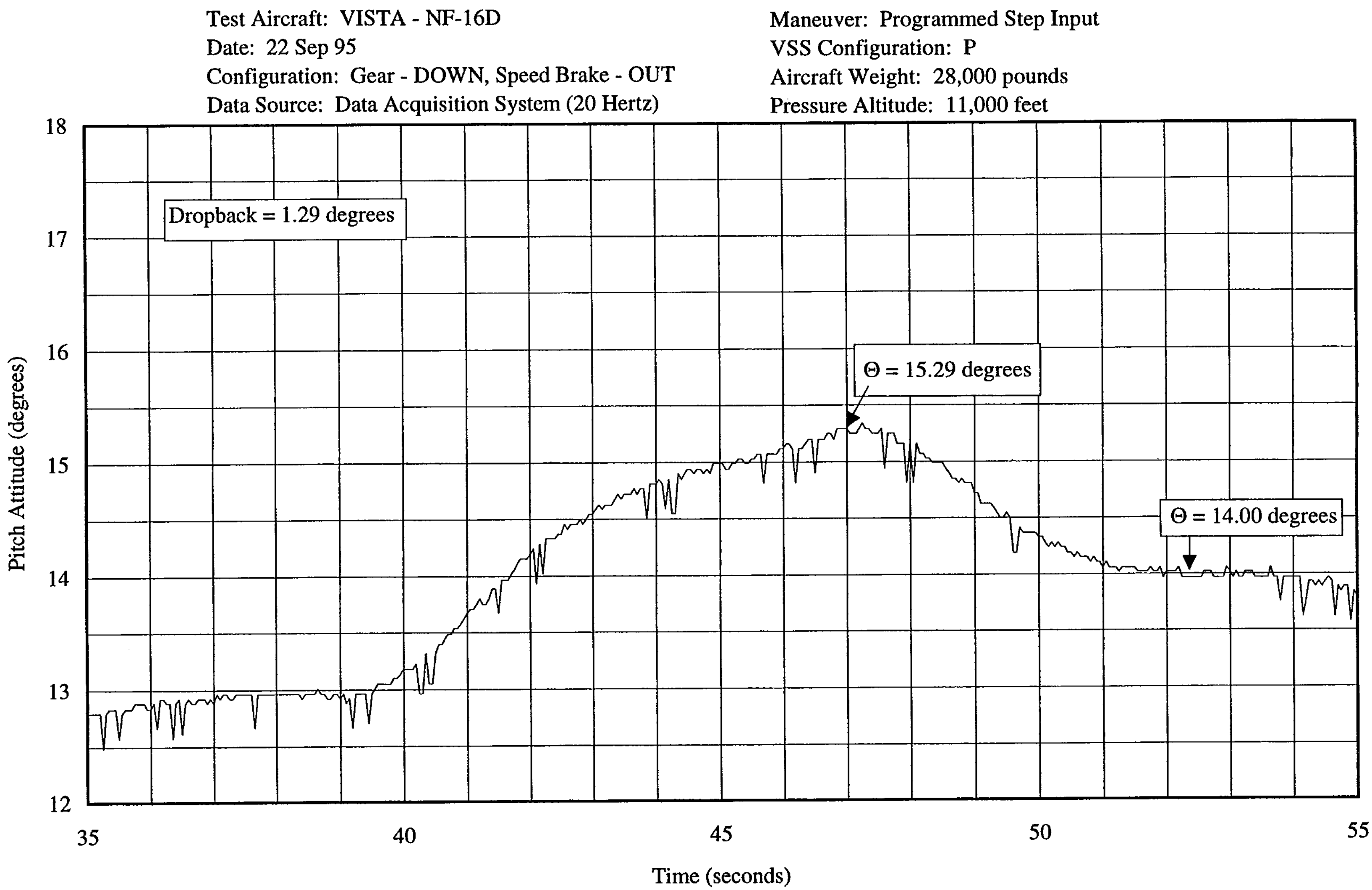

Figure J114 VSS Configuration P Pitch Angle Dropback

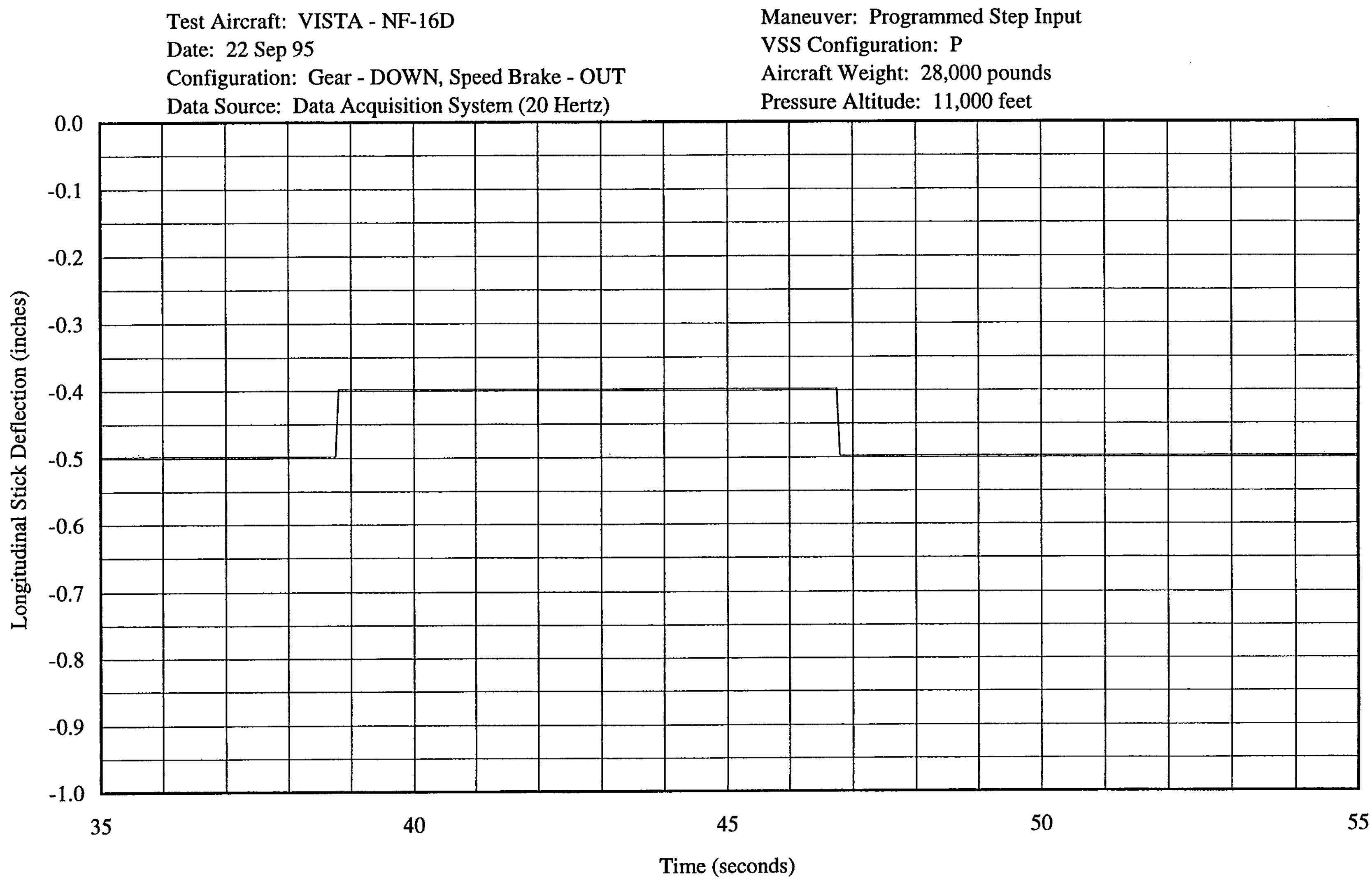

Figure J115 VSS Configuration P Pitch Input Dropback

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: P
Pilot: 2
Test Point: 3.5
Aircraft Weight: 24,500 pounds

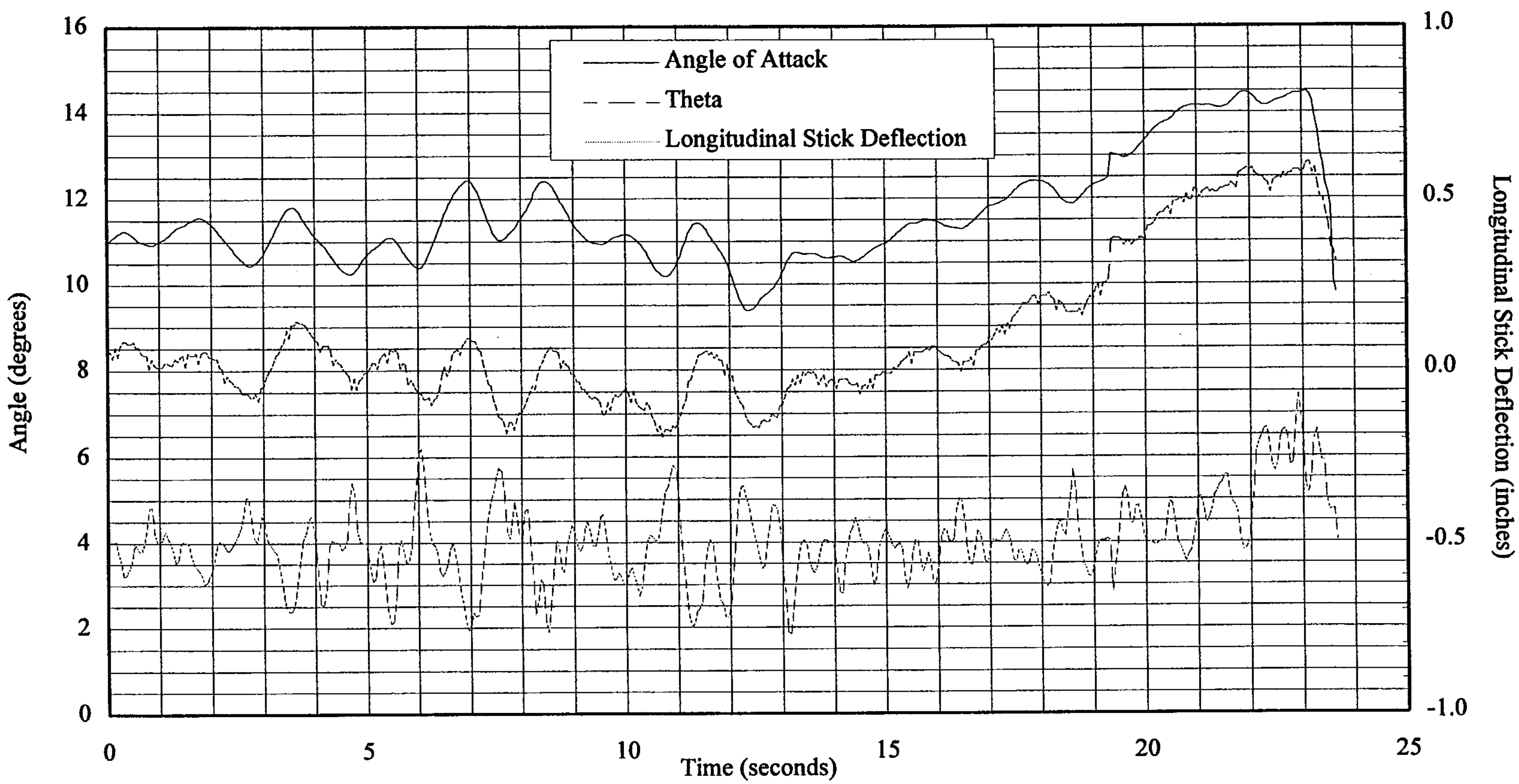

Figure J116 VSS Configuration P Time History of Theta and Longitudinal Stick Deflection

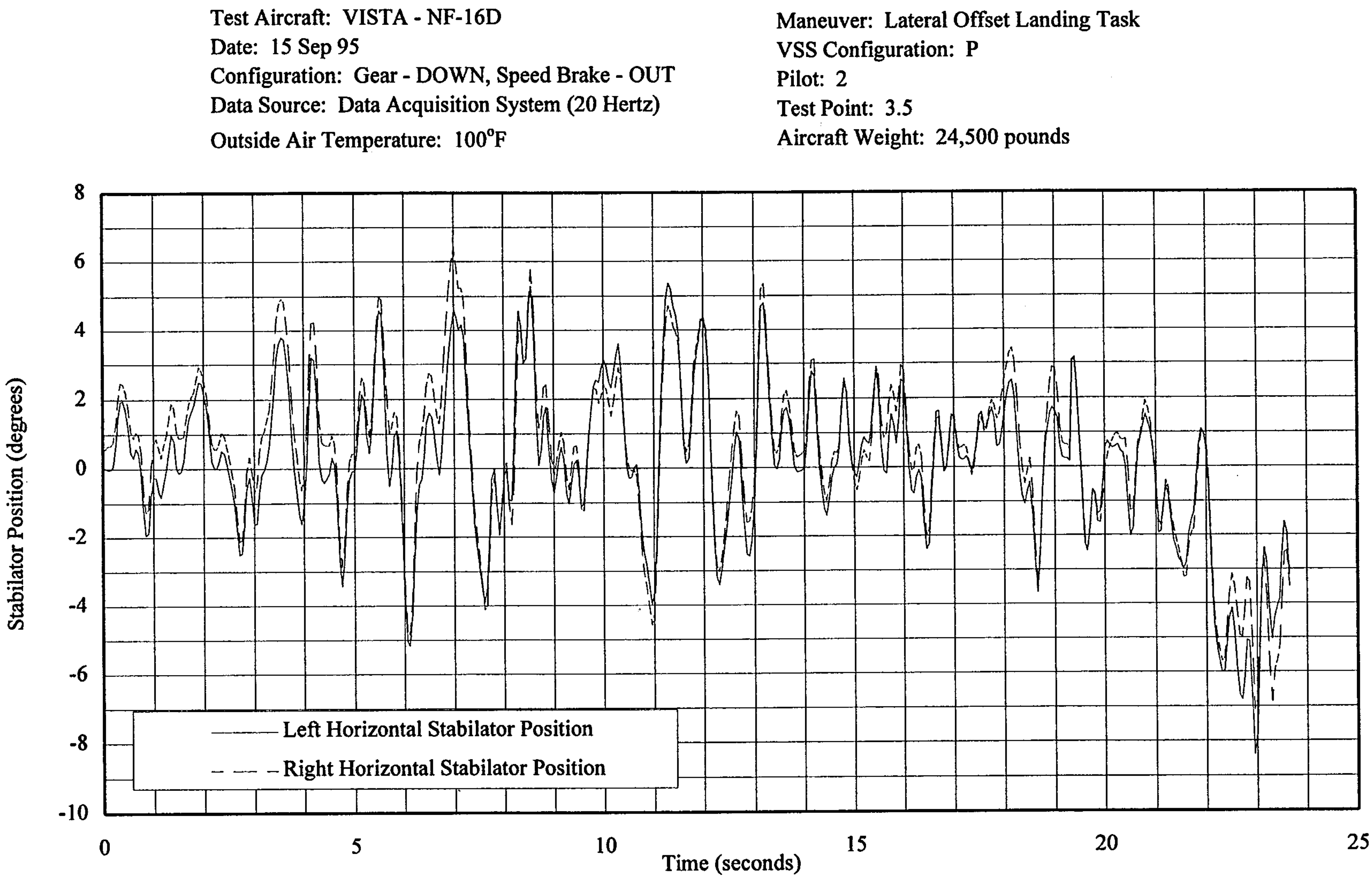

Figure J117 VSS Configuration P Time History of Stabilator Movement

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: P
Pilot: 2
Test Point: 3.5
Aircraft Weight: 24,500 pounds

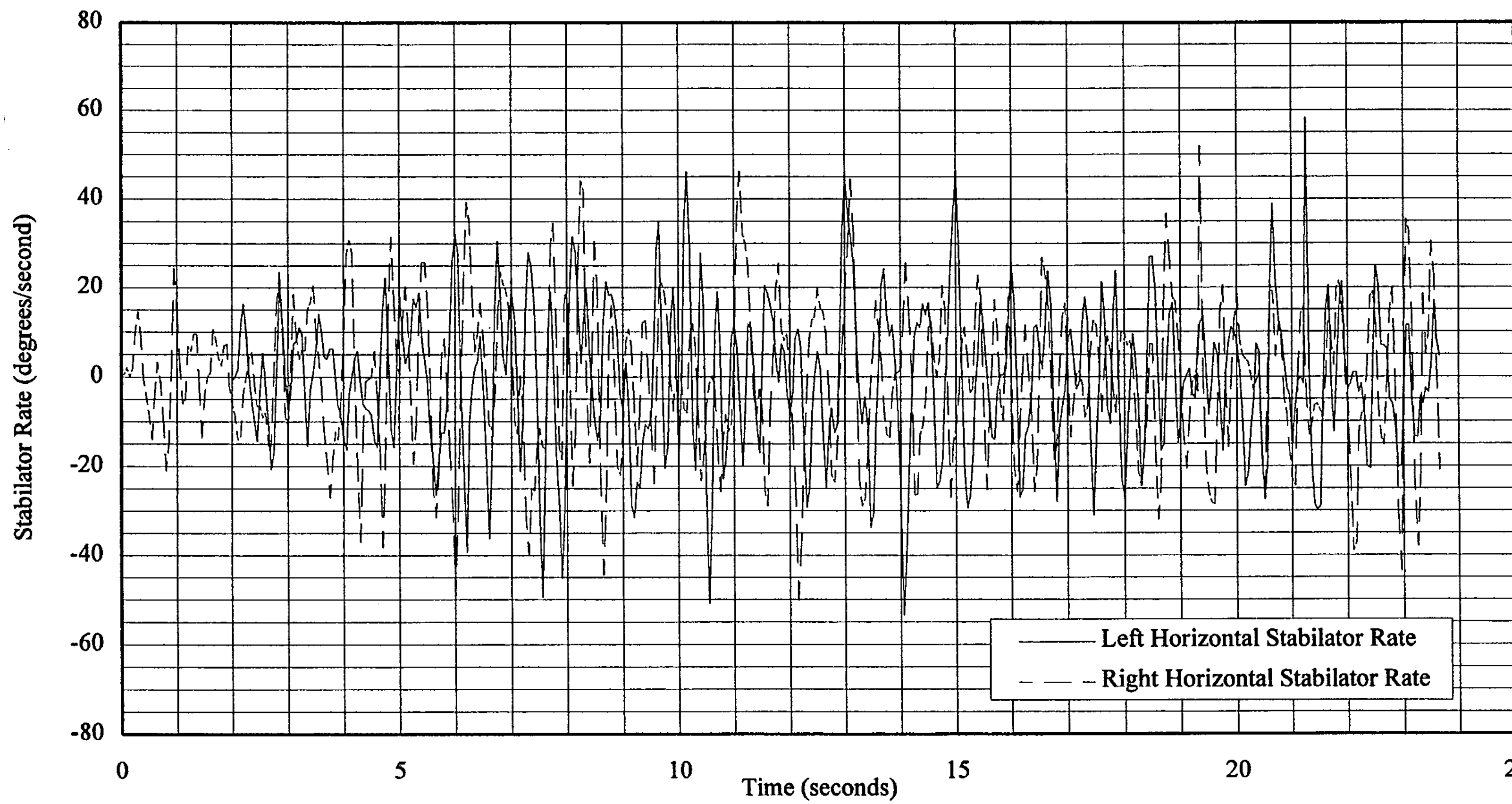

Figure J118 VSS Configuration P Time History of Stabilator Rate

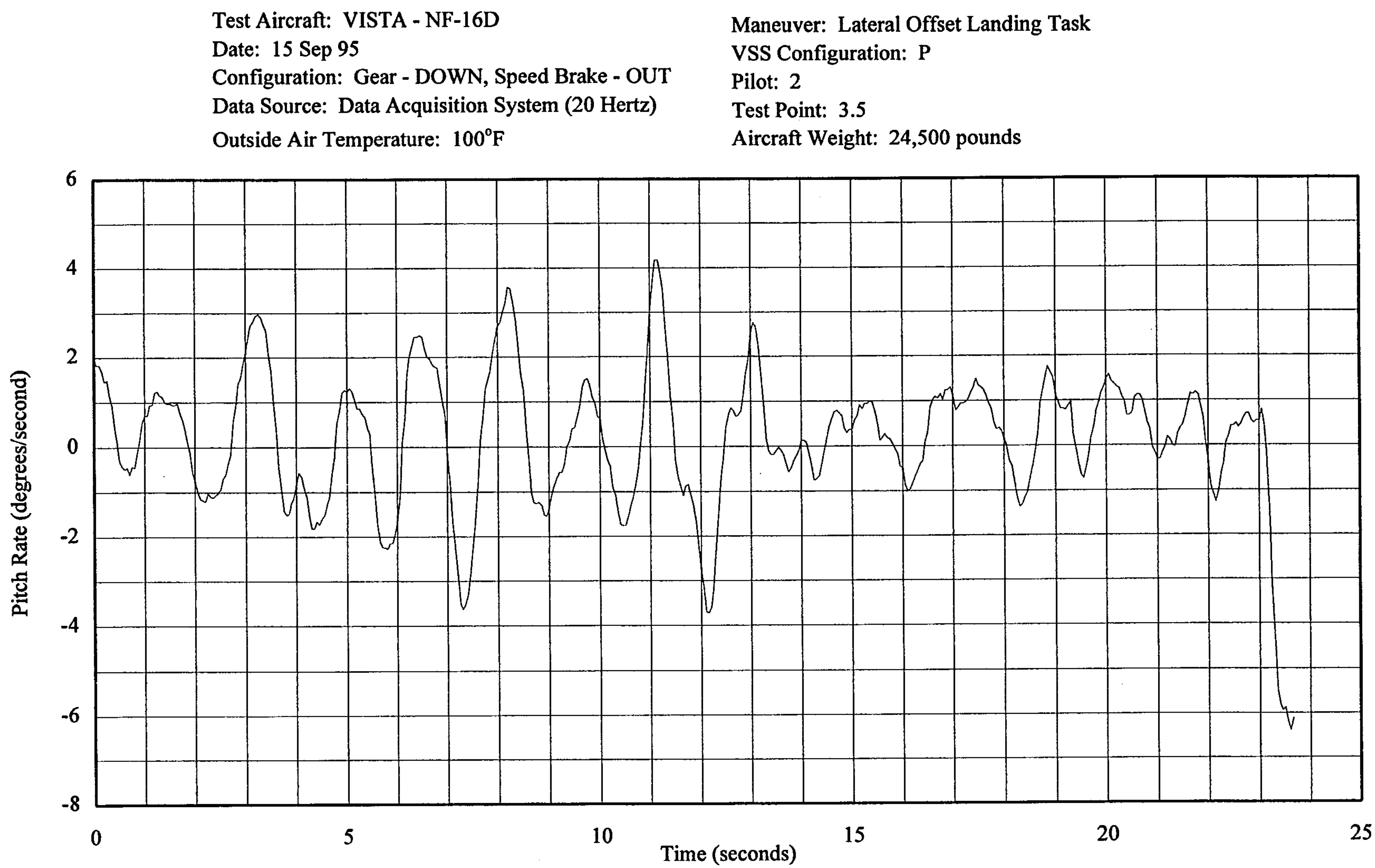

Figure J119 VSS Configuration P Time History of Pitch Rate

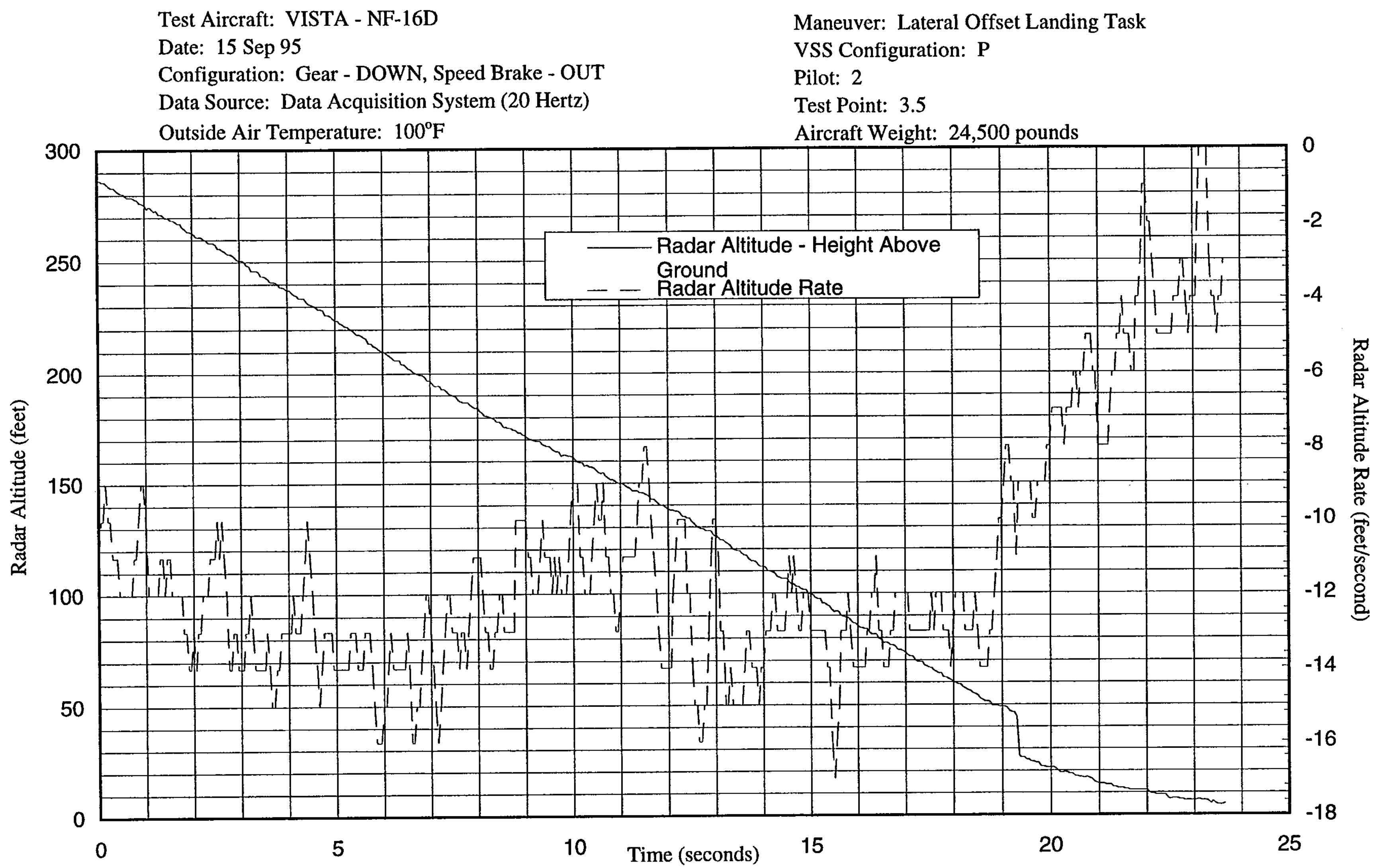

Figure J120 VSS Configuration P Time History of Altitude and Descent Rate

Test Aircraft: VISTA - NF-16D
Date: 15 Sep 95
Configuration: Gear - DOWN, Speed Brake - OUT
Data Source: Data Acquisition System (20 Hertz)
Outside Air Temperature: 100°F

Maneuver: Lateral Offset Landing Task
VSS Configuration: P
Pilot: 2
Test Point: 3.5
Aircraft Weight: 24,500 pounds

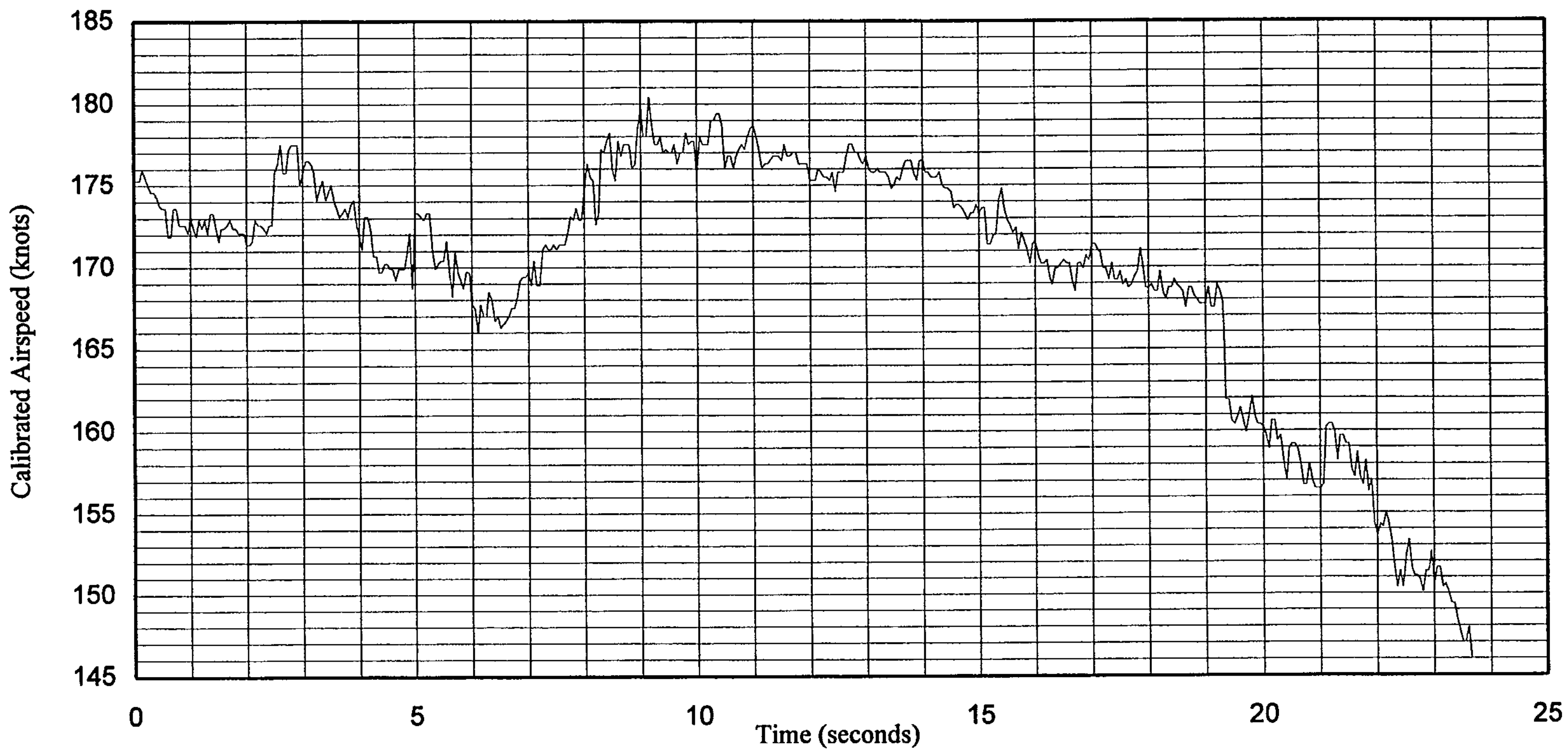

Figure J121 VSS Configuration P Time History of Calibrated Airspeed

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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

Abbreviation	Definition	Units
AFB	Air Force Base	---
AFFTC	Air Force Flight Test Center	---
AFIT	Air Force Institute of Technology	---
AFMC	Air Force Materiel Command	---
AGL	above ground level	---
AMRAAM	advanced medium-range air-to-air missile	---
AOA	angle of attack	---
AOS	angle of sideslip	---
ASCII	American Standard Code for Information Interchange	---
CAP	control anticipation parameter	$1/g*sec^2$
C-H	Cooper-Harper	---
C_{l_α}	lift curve slope	---
DAS	data acquisition system	---
DFLCS	digital flight control system	---
Drb	dropback	---
ELIC	engage logic and interface chassis	---
FPM	flightpath marker	---
FRA	frequency response analysis	---
FTT	flight test technique	---
g	acceleration due to gravity	$32.2\ fps^2$
HQDT	handling qualities during tracking	---
HUD	head-up display	---
Hz	hertz	---
ILS	instrument landing system	---
KIAS	knots indicated airspeed	---
KTAS	knots true airspeed	---
kts	knots	---
LOES	lower order equivalent system	---
MFD	multifunction display	---
MIL-STD	military standard	---
MSL	mean sea level	---
max	maximum	---
min	minimum	---

LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS (Concluded)

Abbreviation	Definition	Units
n/α	change in normal load factor due to a change in angle of attack	g/radian
OAT	outside air temperature	deg
PIO	pilot induced oscillation	---
PTI	programmed test input	---
q	dynamic pressure	lbs/ft^2
REC	recorder	---
S	reference area	---
SCC	signal conditioning chassis	---
T_{Θ_2}	high frequency zero	---
TMP	Test Management Project	---
TPS	USAF Test Pilot School	---
UHF	ultra high frequency	---
USAF	United States Air Force	---
V	true velocity	---
VHF	very high frequency	---
VHS	video home system	---
VISTA	Variable-Stability In-Flight Simulator Test Aircraft	---
VSS	variable stability system	---
Vz	z-axis component of aircraft velocity	---
W	aircraft weight	lb
WL/FIGC	Flight Dynamics Laboratory, Wright Laboratory	---
τ_θ	lower order equivalent system time delay	sec
τ_p	estimated phase delay	sec
ω_{sp}	short period natural frequency	---
ω_{BW}	bandwidth frequency	---
ω_{BW_g}	bandwidth defined by gain	---
ω_{BW_p}	bandwidth defined by phase	---
ζ_{sp}	short period damping ratio	---

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